Status of two West Greenland Caribou populations 2005

1) Akia-Maniitsoq
2) Kangerlussuaq-Sisimiut

Technical Report No. 61, 2005
Greenland Institute of Natural Resources

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3) Akia-Maniitsoq

4) Kangerlussuaq-Sisimiut

By

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Summary

In March 2005 two stocks, Kangerlussuaq-Sisimiut and Akia-Maniitsoq were surveyed by helicopter for abundance and herd structure. Methods and analysis followed Cuyler et al. (2003). Recommended stocking densities are exceeded by ca 60,000 caribou in the Kangerlussuaq-Sisimiut population and ca 17,500 in the Akia-Maniitsoq. The 2005 calf percentage and recruitment are low. There is also a decrease in the ratio of bulls to cows. The low production and the skewed sex ratio may become more pronounced in future. Hunting pressure is not suspected to be a major cause for these changes, because the low harvest numbers can have had little effect on these large populations. Although quantitative data is lacking, it seems that density dependent effects are causing higher mortality rates among calves, and perhaps even among bulls, in the Kangerlussuaq-Sisimiut and Akia-Maniitsoq populations. Given that densities are three to six-times the recommended target value considered sustainable, we expect strong competition between individuals for available food resources. If the stocks are allowed to continue at their current size or increase further, there is a clear risk of lasting damage to the ranges, e.g. overgrazing and trampling. Unsustainable range use may compromise the future health and viability of caribou stocks in West Greenland. Regardless of management initiatives taken now, population crashes may be inevitable for some West Greenland herds within the foreseeable future, but accurate predictions about herd trends are impossible. To understand approaching developments the caribou and their range must be studied within the wider context of global warming and associated climate change.

Akia-Maniitsoq herd – Central region

The estimate for pre-calving population size of Akia-Maniitsoq herd of the Central region in March 2005 is ca 35,807 caribou (27,474 - 44,720; 90% CI). Caribou density in 2005 was 3.0 caribou per km^2 in the high-density stratum, and 1.1 per km^2 in the low-density stratum. Mean group size was 4.33 ± 2.91 S.D. in 2005. Late winter calf percentage was a low 14%, as was the annual recruitment of 24 calves per 100 cows. The bull to cow ratio was only 0.45. If natural mortality is between 8 and 10% then on a herd this size between 2,200 and 4,500 animals may be expected to die annually of natural causes.

Kangerlussuaq-Sisimiut herd – North region

The estimate for pre-calving population size of Kangerlussuaq-Sisimiut herd of the North region in March 2005 is ca 90,464 caribou (70,276 – 113,614; 90% CI). Caribou density in 2005 was 6.2 caribou per km^2 in the high-density stratum, and 2.3 per km^2

in the low-density stratum. Mean group size was 4.63 ± 3.38 S.D. in 2005. Late winter calf percentage was a low 11%, as was the annual recruitment of 16 calves per 100 cows. The bull to cow ratio was only 0.33. If natural mortality is between 8 and 10% then on a herd this size between 5,600 and 11,400 animals may be expected to die annually of natural causes. Since the calf percentage is approaching the natural mortality value, this population may be approaching its theoretical carrying capacity where births equal deaths, i.e. production equals zero.

Eqikkaaneq

Tuttoqarfinni Kangerlussuaq-Sisimiut kiisalu Akia-Maniitsoq qulimiguulik atorlugu marts 2005-imi kisitsisoqarpoq. Kisitsineq iluatsillugu tuttoqarfinni taakkunani tuttut eqimassusiat tuttullu ataatsimoortut qanoq aaqqissuunneqartarsimanerat ilanngullugu misissuiffigineqarpoq. Kisitseriaaseq misissueriaatsillu 2003-mi Cuyler allallu allaaserisimasaat malillugit ingerlanneqarput. Tuttut eqimassusissaannut innersuussutit naapertorlugit tuttoqarfimmi Kangerlussuaq-Sisimiut-mi tuttut 60.000-t missaannik amerlavallaalersimapput, kiisalu tuttoqarfimmi Akia-Maniitsumi 17.500-t missaannik amerlavallaalersimallutik. 2005-imi kisitsinermi tuttoqatigiit tamakkerlugit isiginiarlugit piaqqat amerlassusiat ikigisassaavoq. Kisitsinermi aamma maluginiagassaavoq pannerit amerlassusiat kulavaat norraatsullu amerlassusiannut sanilliullugit ikiliartulersimanerat. Piaqqiaasartut ikiliartulernerat aammalu tuttut amerlassusiat eqqarsaatigalugu suiaassutsimikkut kipunganerat siunissami malunnaateqarnerulersinnaavoq. Allannguutinut pineqartunut piniagaanerinut tunngassuteqartut peqqutaasimanavianngillat, tassami tuttoqarfinni taakkunani tuttorpassuaqarnera eqqarsaatigalugu pisaasartumerngit annertunerusumik sunniuteqarsimanavianngimmata. Naak paasissutissat suli amerlanerusut pisariaqartikkaluarlugit tamaattoq ilimagaarput norraat allaallu immaqa pannerit akornanni toquinnartartunik naammattuuisarnerit tuttut amerlavallaarnerinik peqquteqarsimassasoq. Piujuaannartitsinissaq anguniarlugu tuttut amerlassusissaattut innersuussutinut sanilliullugu maanna tuttut pingasoriaammiit allaat arfinileriaat angullugu amerlanerulersimapput, taamaattoqarneralu peqqutaalluni naatsorsuutigineqartariaqarpoq nerisassarsiorlutik sakkortuumik unammisarsimanissaat. Tuttut maannatuut amerlatigiinnassappata imaluunniit amerliartuinnavissappata nunap neriniarfiusartup innarlerneqarsinnaanissaa ilimanaateqarluinnarpoq, tassa naggorlutsilluni imaluunniit tummaatarineqarpallaarnermigut aserorneqarluni. Taama piujuaannartitsinissamik tunngaveqanngitsumik neriniarfinnik atuititsineq ingerlaannassappat Kalaallit Nunaata kitaani tuttut peqqissusiat aammalumi uumaniaannarsinnaanissaat ajornartorsiortinneqaleraluttuinnassaaq. Tuttoqassuseq mianeriniarlugu aqutsinikkut periusissat suulluunniit maannakkut atuutitinneqaleraluarpata Kalaallit Nunaata kitaani tuttoqarfiit ilaanni siunissami qaninnerusumi tuttut tassanngaannartumik ikileriarujussuaratarsinnaanissaannik periarfissaq pinngitsoortinneqarsinnaagunanngilaq. Taamaakkaluartorli tuttoqassutsip siunissami qanoq allannguuteqarsinnaanissaa siorngeruminaatsorujussuuvoq. Tuttoqassutsip siunissami allannguuteqarsinnaanissaa paasisaqarfigerusunneqarpat maannamut mississugaasartunut sanilliullugu misissuinernik siamasinnerusunik, tassa neriniarfiinut tunngassuteqartunik misissuinernik aammalu silaannaap kissatsikkiartornerata kingunerinik misissuinernik, ilaqartinneqartariaqarput.

Tuttoqarfik Akia-Maniitsoq – Qeqqa

Kalaallit Nunaata tuttoqarfittut immikkoortua Qeqqa, tuttoqarfik Akia-Maniitsoq, martsimi 2005 tuttut piaqqiulinnginnerisa nalaani amerlassutsimikkut missingiunneqarput 35.807-inut (27.474 – 44.720; 90 % KI). Tamaani tuttut amerlanerpaaffiini kvadratkilometerimut amerlassusiat 3,0-imiippoq, ikinnerpaaffiinilu 1,1-imiilluni. Agguaqatigiissillugu ataatsimoortut 2005-imi amerlassusiat 4,33±2,91 SD-miippoq. 2005-imi ukiuunerani norraat amerlassusiat appasippoq 14 %-imiilluni, taamatullu aamma kulavaat 100-gaangata norraat amerlassusiat 24-ulluni. Pannerit arnavissallu nikingassusiat tamaallaat 0,45-juvoq. Toquinnartartut amerlassusiat 8-10 %-imiippat tuttoqarfimmi Akia-Maniitsutut ittumi toquinnartartut amerlassusiat ukiumut 2.200 aamma 4.500 akornanniissapput.

Tuttoqarfik Kangerlussuaq-Sisimiut – Avannaa

Kalaallit Nunaata tuttoqarfittut immikkoortua, tuttoqarfik Kangerlussuaq-Maniitsoq, martsimi 2005 tuttut piaqqiulinnginnerisa nalaani amerlassutsimikkut missingiunneqarput 90.464-inut (70.276-113.614; 90 % KI). Tamaani tuttut amerlanerpaaffiini kvadratkilometerimut amerlassusiat 6,2-miippoq, ikinnerpaaffiinilu 2,3-miilluni. Agguaqatigiissillugu ataatsimoortut 2005-imi amerlassusiat 4,63±3,38 SD-miippoq. 2005-imi ukiuunerani piaqqat amerlassusiat appasippoq 11 %-imiilluni, taamatullu aamma arnavissat 100-gaangata piaqqat amerlassusiat 16-iulluni. Pannerit arnavissallu nikingassusiat tamaallaat 0,33-uvoq. Toquinnartartut amerlassusiat 8-10 %-imiippat tuttoqarfimmi Kangerlussuaq-Sisimiutut ittumi toquinnartartut amerlassusiat ukiumut 5.600 aamma 11.400 akornanniissapput. Piaqqat amerlassusiat toquinnartartut amerlassusiat nallersimalermagu imaarataannaavoq tamaani tuttoqassutsip killissani tikissimassagaa, tassa piaqqat toquinnartartullu amerlaqatigiilermata tuttut amerliartorunnaarsimassallutik.

Resume

I marts 2005 blev bestandstætheden og flokstrukturen af to rensdyrbestande, Kangerlussuaq-Sisimiut og Akia-Maniitsoq, bestemt ved helikopter-optælling. Metoder og analyser var de samme som i Cuyler et al. (2003). Den anbefalede floktæthed er overskredet

med ca. 60.000 rener i Kangerlussuaq-Sisimiut-populationen og ca. 17.500 i Akia-Maniitsoq-populationen. Både andelen af kalve og rekrutteringen er lav i 2005. Der ses også et fald i antal af bukke i forhold til simle. Den lave produktion og den skæve kønsfordeling kan blive mere udtalt fremover. Jagttrykket menes ikke at være en væsentlig årsag til disse ændringer, da det lave fangstantal ikke kan have haft nogen større effekt på så store populationer. Selv om vi mangler kvantitative data, ser det ud til, at tæthedsafhængige effekter forårsager højere dødelighed blandt kalvene, og måske endda også blandt bukkene i Kangerlussuaq-Sisimiut- og Akia-Maniitsoq-populationen. Idet tæthederne er tre til seks gange højere end den anbefalede målværdi, der anses for at være bæredygtig, forventer vi, at konkurrencen mellem dyrene om de tilgængelige føderessourcer er hård. Hvis bestandenes størrelse får lov at fortsætte på det nuværende niveau eller øges yderligere, er der en klar risiko for varige skader på græsningsarealerne, fx i form af overgræsning og nedtrampning. Ikke-bæredygtig udnyttelse af græsningsarealerne kan blive en trussel for rensdyrbestandenes fremtidige sundhedstilstand og levedygtighed i Vestgrønland. Uanset hvilke forvaltningsmæssige forholdsregler der tages nu, kan bestandssammenbrud være uundgåeligt for nogle af Vestgrønlands rensdyrflokke inden for en overskuelig fremtid, men det er umuligt at forudsige flokudviklingen præcist. Skal vi forstå den fremtidige udvikling, må rensdyrene og deres græsningsarealer studeres i en bredere sammenhæng, som også omfatter den globale opvarmning og de medfølgende klimaforandringer.

Akia-Maniitsoq-bestanden – Region Midt

Akia-Maniitsoq-bestanden i Region Midt anslås i marts 2005 at have en populationsstørrelse før kælvning på ca. 35.807 rener (27.474-44.720; 90 % KI). Rensdyrtætheden var i 2005 på 3,0 rener pr. km^2 hvor tætheden var størst, og 1,1 pr. km^2 hvor tætheden var mindst. Den gennemsnitlige flokstørrelse var 4,33 ±2,91 SD i 2005. Senvinter-andelen af kalve var lav, 14 %, og ligeså den årlige rekruttering på 24 kalve pr. 100 simle. Forholdet mellem bukke og simle var på kun 0,45. Ved en naturlig dødelighed på 8-10 %, vil man i en flok på denne størrelse kunne forvente at se en naturlig dødelighed på mellem 2200 og 4500 dyr om året.

Kangerlussuaq-Sisimiut-bestanden – Region Nord

Kangerlussuaq-Sisimiut-bestanden anslås i marts 2005 at have en populationsstørrelse før kælvning på ca. 90.464 rener (70.276-113.614; 90 % KI). Rensdyrtætheden var i 2005 på 6,2 rener pr. km^2 hvor tætheden var størst, og 2,3 pr. km^2 hvor tætheden var mindst. Den gennemsnitlige flokstørrelse var 4,63 ±3,38 SD i 2005. Senvinter-andelen af kalve var lav, 11 %, og ligeså den årlige rekruttering på 16 kalve pr. 100 simle. Forholdet mellem bukke og simle var på kun 0,33. Ved en naturlig dødelighed på 8-10 %, vil man i en flok på denne størrelse kunne forvente at se en naturlig dødelighed på mellem 5600 og 11.400 dyr om året. Da andelen af kalve nærmer sig den naturlige dødelighed, kan denne bestand være på vej mod sin teoretiske bærekapacitet, hvor fødsler er lig med dødsfald, dvs. produktionen er lig nul.

Introduction

Caribou (*Rangifer tarandus groenlandicus*) have no natural predators in West Greenland, and none have existed for several hundred years (Dawes et al. 1986). When combined with their high fertility (Cuyler & Østegaard 2005) and recruitment (Cuyler et al. 2002, 2003, 2004), this would suggest that overabundance may be their greatest threat. Several boom and crash cycles of caribou in West Greenland have been noted since the 1700's (Vibe 1967, Meldgaard 1986), and recent population estimates are the highest ever documented, indicating that a new crash might be expected in the near future.

Past population estimates

Total caribou abundance in West Greenland may have been about 100,000 animals in the late 1960's with a proposed crash to about 16,000 animals by 1978 (Clausen et al. 1980, Roby & Thing 1985). Following unsystematic surveys the estimates were 7-9,000 in 1980 and 15,000 in 1982 (Strandgaard et al. 1983). During that period there was little correlation between the population estimates and government harvest statistics. Over 6,000 caribou were harvested in 1980, and over 9,000 in both 1982 and 1983 (Born et al. 1998). Those harvest numbers would not have been possible if the aerial survey estimates of 1980-82 had been close to accurate. No critisicm of the population estimates occurred, perhaps because the public was unaware of them and hunting remained unregulated.

Systematic aerial surveys completed in the 1990's suggested that caribou in West Greenland were few in number. In 1993 the estimate was about 7-9,000 caribou, and in 1996 about 20-22,000 (Ydemann & Pedersen 1999). Local knowledge contradicted the low estimates. Therefore, the accuracy of these estimates was hotely debated and created much public anger because hunting was first prohibited for 2 years and then heavily regulated for the first time.

All surveys have intrinsic errors and biases. Given the methods employed in the 1990's (high speed, high altitude, wide strip width, long transect length, sun glare, inability to maintain constant altitude, etc.), it is likely that these surveys underestimated populations in West Greenland because a large number of caribou present within the area of the transects were not seen (Cuyler et al. 2002, 2003).

Recent population estimates

The West Greenland caribou populations of Kangerlussuaq-Sisimiut (North region) and Akia-Maniitsoq (Central region) (Figure 1), were surveyed by helicopter in March 2000 and 2001. These surveys employed new methods designed to reduce the negative bias of missed caribou (significantly slower flight speeds, lower and constant flight altitudes, narrowed strip width, and shorter transects, correction for missed caribou, etc.). The resulting pre-calving population estimate was ca. 51,600 for the Kangerlussuaq-Sisimiut population, and ca. 46,200 caribou for the Akia-Maniitsoq population. These are 5 and 7 times greater than the 1996 estimates. Many caribou meant that densities had reached 3-4 caribou per sq km (Table 1), which could negatively affect forage quality and quantity. In Scandinavia, sustaining stocking densities above 2 caribou per sq km can lead to overgrazing of the vegetation and population crashes (Helle et al. 1990).

Recent harvest management

Given the large population estimates of 2000-2001, harvest recommendations to the Greenland Homerule government advised no further population increase for these two herds and tentatively suggested decreasing the populations (Linnell et al. 2001, Kingsley & Cuyler 2002). Out of concern for preserving the vegetation and to promote sustainable use, caribou density on the range was advised to be kept below a density that might threaten forage quality and availability. Despite the lack of studies of carrying capacity on West Greenland ranges, in the 2002 harvest advice an imprecise target density of 1.2 caribou per sq km was set. Therefore, the Greenland government issued 13,300 caribou licences in 2000, then 24,300 in 2001, followed by 36,150 in 2002, which in practice became an open (unlimited) harvest. In an effort to reduce caribou number and density, open harvests were continued in 2003, 2004 and 2005.

Traditionally the majority of animals harvested are males (Loison et al. 2000), however, removing more females was recommended to achieve reductions in abundance and density. Since a female-only harvest was deemed unsuitable to implement, instead the hunting season was extended into the rut and beyond since rutting males are considered inedible. Further, it was permitted to take the calf, and the hunting season lengthened three to seven-fold. From 1996 until 1999 the length of the hunting season never exceeded 27 days, 15 August to 10 September, for both sport and commercial hunters. In contrast, by 2004 the sport hunter season was 92 days, with commercial hunters receiving an additional 90 days. The season began 1 August 2004, paused for the month of November, and finished at the end of February 2005.

Present survey

Had the management strategies implemented since 2000 reduced caribou abundance or density? In March 2005 an aerial survey by helicopter examined the two largest herds in West Greenland, the Kangerlussuaq-Sisimiut caribou population of the North region, and the Akia-Maniitsoq populations of the Central region. This report presents current abundance and herd structure for these two populations.

Table 1. *Recent late winter herd parameters of the Kangerlussuaq-Sisimiut and Akia-Maniitsoq stocks in West Greenland (Cuyler et al. 2002, 2003).*

Parameter	1998	2000	2001
Kangerlussuaq-Sisimiut caribou stock – (2) North region			
Mean group size ± SD	3.1	2.7	-
Density per sq km	-	1.2 - 2.8	-
Calf percentage	21%	27%	-
Recruitment, Calves / 100 Cows	48	68	-
Bull to Cow Ratio	0.86	0.83	-
Akia-Maniitsoq caribou stock – (3) Central region			
Mean group size ±SD	6.4	-	3.2
Density per sq km		-	1.1 - 4.0
Calf percentage	25%	-	17 %
Recruitment, Calves / 100 Cows	65	-	31
Bull to Cow Ratio	0.92	-	0.58

Figure 1. *Locations of the two West Greenland caribou populations, Akia-Maniitsoq and Kangerlussuaq-Sisimiut, in the North and Central regions.*

Methods

Survey design and field methods

In March 2005 we completed aerial transect surveys for two caribou populations in two regions; Kangerlussuaq-Sisimiut (North region) and Akia-Maniitsoq (Central region). Areas defined included islands, lakes and rivers, but deleted Ice Caps and glaciers. We stratified both regions into areas of low and high caribou density prior to assigning random transects (Appendix 1). This stratification was based on the observed densities from earlier aerial surveys (Ydemann & Pedersen 1999, Cuyler et al. 2002). Transect location and directions were randomly generated. Transect length was 7.5 kilometres. In addition to Greenland Institute of Natural Resources research biologist, Christine Cuyler, we employed three local observers, which included two professional KNAPK hunters from Nuuk, Rink Heinrich & Johannes Egede, as well as the Sisimiut wildlife officer, Hans Mølgaard.

Negatively biased population estimates arise if, among other things, survey design makes it impossible to spot caribou present on a transect flown. While it is difficult to completely overcome this bias, it can be minimised. We have observed that it is necessary to fly low, slow and concentrate on a narrower strip width for shorter lengths of time (Cuyler et al. 2002, 2003, 2004). Observers need time to scan the strip area thoroughly and observer fatigue must be minimized. Thus we applied the methods of Cuyler et al. (2003) again in the 2005 surveys.

We used a AS350 helicopter (OY-HIZ), which could follow terrain features, while maintaining a constant altitude above ground level. We flew at 46-65 km/hour. Ambient wind direction and speed determined the necessary flight speed to remain airborne. We maintained a constant altitude of 15 metres (50 feet). Transect strip width was 300 metres to either side of the helicopter, for a total strip width of 600 metres. Before departing the airport we ascertained the 300 metre strip width using distance-finder binoculars, i.e. hovering at the 15 m altitude, we measured a distance of 300 m to the broadside of the airplane hanger wall. Each observer marked their window with masking tape at the point at which the hangar wall met the tarmac. The tape functioned as a guide for the 300 m strip width while flying transects.

Solar glare reflecting off the snow surface may reduce sightability of caribou and cause observer fatigue. Thus it was important that observers did not look directly into the sun when flying a transect. We chose flight direction accordingly. March was selected because caribou group size variability is low and less than 6 animals in late winter (Roby & Thing 1985, Thing 1982, Thing & Falk 1990, Ydemann & Pedersen 1999, Cuyler et al. 2002, 2003). The low variability reduces sampling error and aids precision. March also has an optimal day length and snow cover, and patchy snow cover is known to reduce sightability (Ydemann & Pedersen 1999). Further, caribou movement is relatively low in March. Straight line caribou movements averaged < 1 km per day and did not exceed five kilometres per day, however, in April movement can increase to a mean of < 3 km per day and a maximum of ca 12 km per day (Cuyler & Linnell 2004).

Three observers were in the helicopter. Two counted on the left side and one on the right side. Observers counted caribou independently of each other, with no verbal or other contact between observers while a transect was being flown. We used manual click-counters to log the number of caribou seen on a specific transect by each observer. The number counted by each observer was recorded immediately following each transect, after which click-counters were zeroed.

Failure to detect caribou was considered the most important source of bias (inaccuracy). We had calculated the left front-seat observer ability, i.e. mean missed caribou per transect, from the results of the 2000-2001 surveys (Cuyler et al. 2002, 2003). Rear seat (left and right) observer ability, however, was initially unknown. Therefore the rear seat observers alternated seat position, so each sat on the same side as the known-ability observer several times. Survey details specific to each caribou population studied are given below. Historical backgrounds for each population are available in Cuyler et al. (2002, 2003).

Akia-Maniitsoq caribou population (Central region)

The aerial survey of the Central region occurred 14-16 March 2005. The Central region encompasses approximately 15,362 km^2. The 54 random transect lines were divided between 2 strata, one high and one low caribou density stratum (Figure 2). The high-density stratum involved c. 10,037 km^2, while the low-density stratum encompassed c. 5,325 km^2. 39 transects were allocated to the high caribou density stratum and 15 transects to the low caribou density stratum. Herd structure and recruitment counts were flown on several transects, and over large areas in both the high and low caribou density strata.

Kangerlussuaq-Sisimiut caribou population (North region)

The aerial survey of the Kangerlussuaq-Sisimiut herd occurred 18-22 March 2005. The North region encompasses approximately 26,000 ice-free km^2 . The 60 random transect lines were divided between two strat, one high and one low caribou density stratum (Figure 3). The high-density stratum was 8,000 km^2, and the low-density stratum 18,000 km^2. 40 transects were allocated to the high caribou density stratum, and 20 transects were allocated to the low-density stratum. Herd structure and recruitment counts were flown on several transects, and over large areas in both the high and low caribou density strata.

Figure 2. *Transect lines, with ID numbers, and the stratification used for the 2005 aerial survey of the Akia-Maniitsoq caribou population in the Central region. The area inside blue outline indicates the high caribou density stratum. Elevation is not shown.*

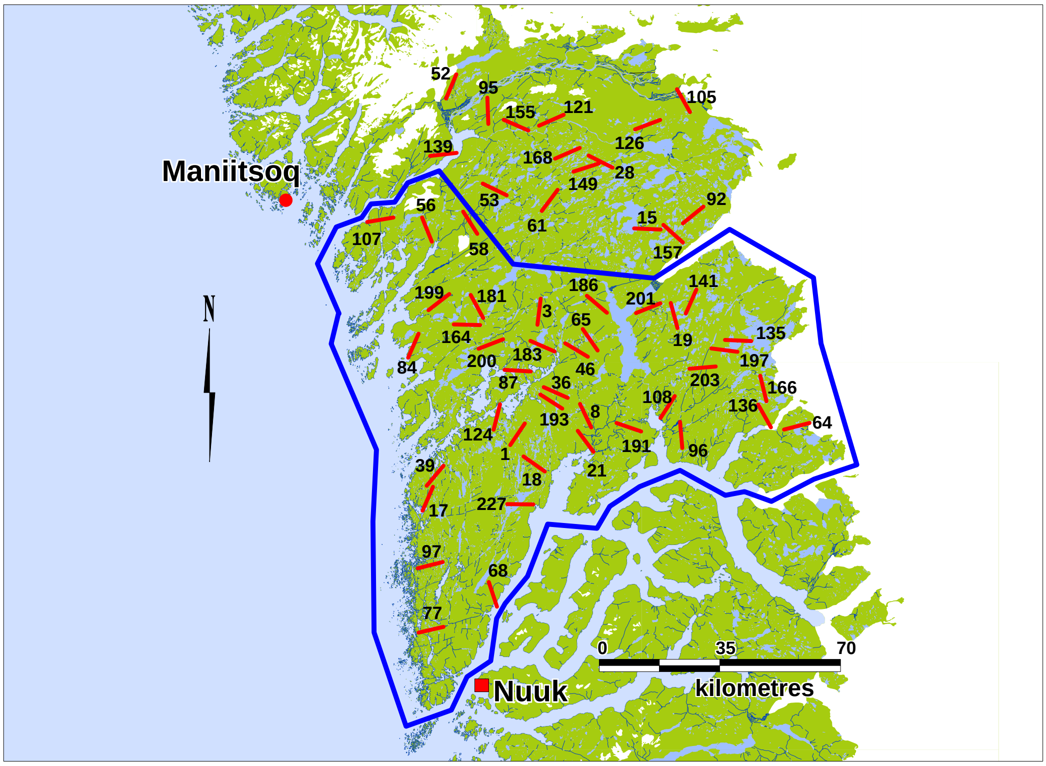
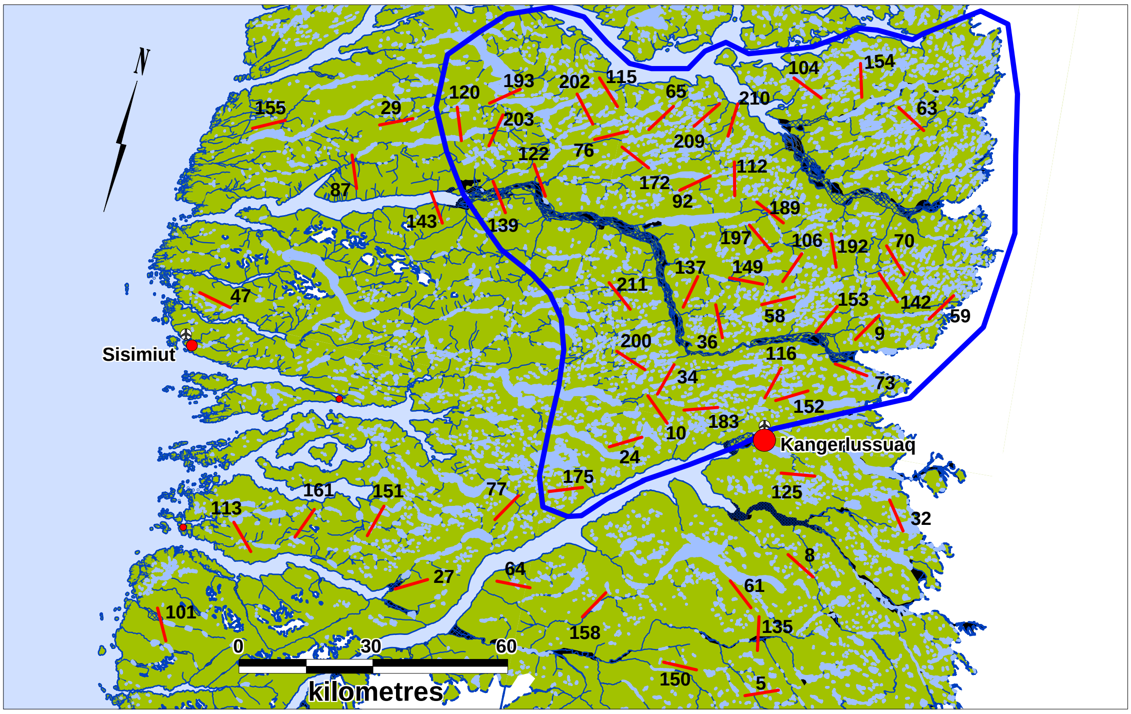


Figure 3. *Transect lines, with ID numbers, and the stratification used for the 2005 aerial survey of the Kangerlussuaq-Sisimiut caribou population in the North region. The area inside blue outline indicates the high caribou density stratum. Elevation is not shown.*



Estimating abundance

Population estimates for the two caribou populations investigated and the minimum number for the missed animals were calculated according to Cuyler et al. (2002, 2003) . The standard method when each missed animal is identified follows Pollock & Kendall (1987).

Statistical design

The aerial helicopter survey was designed as a stratified strip transect count. Each transect had three observers, of which two counted the same strip area, i.e. both counted on the left side of the helicopter. A method to calculate a minimum number for the missed animals was developed. The standard method when each missed animal is identified was as follows Pollock & Kendall (1987). For details see appendices 1, 2 & 3.

Herd structure & calf recruitment

During aerial surveys, herd structure and recruitment counts were obtained by backtracking transects in a zigzag flight pattern, never flying more than ca two kilometres from the transect line, by zigzagging over areas of high caribou density, or by opportunistic observations while flying a transect (Figures 4 and 5). Choice of a transect or area for zigzagging depended on how many caribou were present, since the goal was to maximize the number of caribou, sexed and aged, for herd structure and recruitment. There was close communication between all observers and pilot during zigzagging. All caribou sighted were sexed and aged (< or > 1 year old) following a brief overpass with the helicopter.

Sex was determined by the presence or absence of a vulva and/or urine patch on the rump. This reliably indicated a female on both adults and calves. No other method was 100% certain, e.g. antler size, shape, presence or absence, were not used, as the presence of antlers on female caribou is highly variable in western Greenland. Age was determined by body size. Calves of both sexes were considerably smaller than all other age classes at this time of year. There were two age classes used in subsequent analyses, i.e. calf (≤ 9-10 months old) and adult (> 1 year). Calf percentage given is the percentage of the total number of caribou seen. Calf recruitment is the late-winter calf per 100 cow ratio. Group size was based on proximity and group cohesion during possible flight response.

Figure 4. Central region: Akia-Maniitsoq herd structure zigzag overflight areas (indicated by blue cross-hatching) and transects (the blue transects with ID number highlighted were zigzagged; the red transects indicate where opportunistic observations where obtained). The high caribou density stratum included the area inside the blue outline. Elevation is not shown.

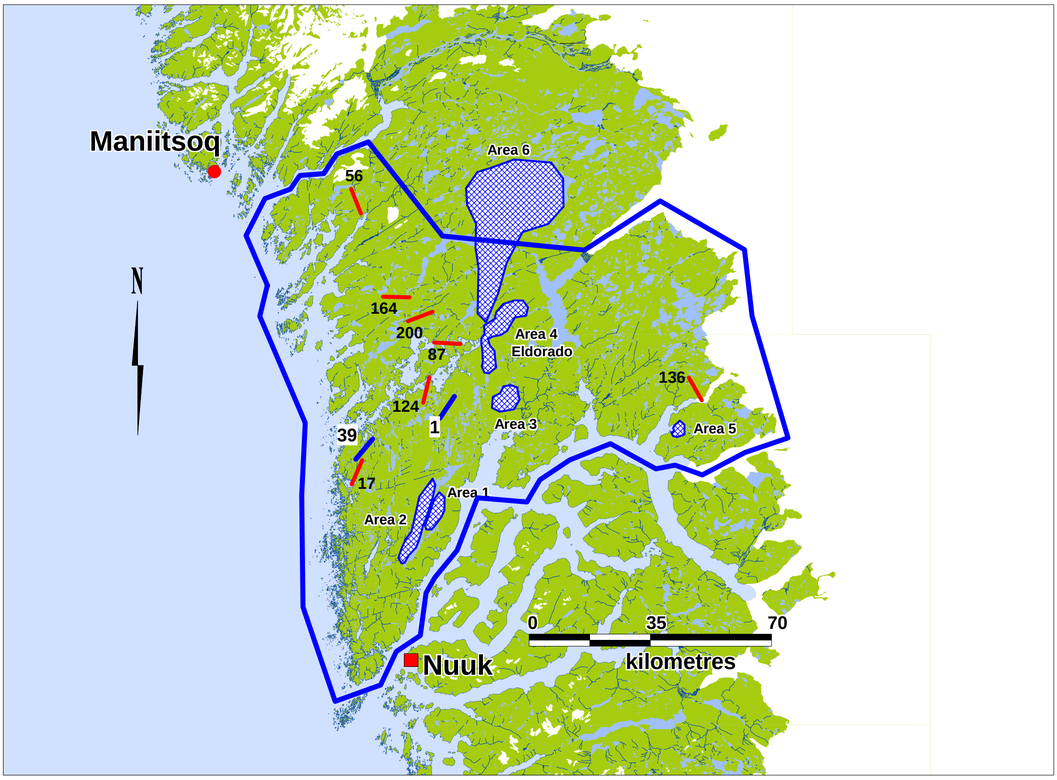
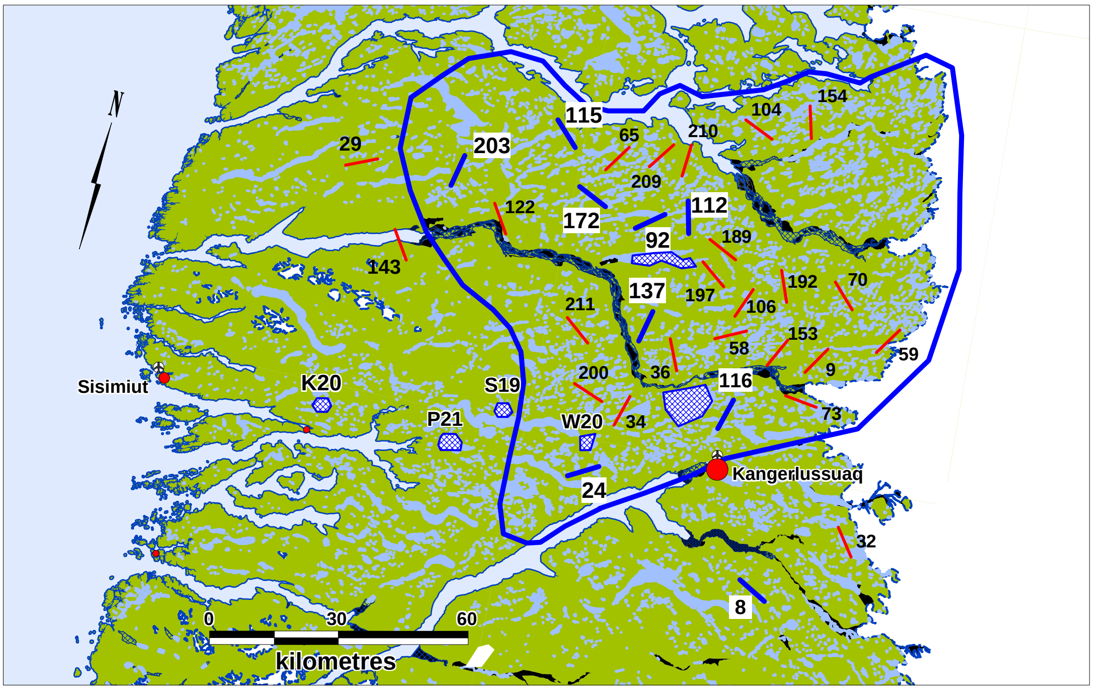


Figure 5. North region: Kangerlussuaq-Sisimiut herd structure zigzag overflight areas (indicated by blue cross-hatching) and transects (the blue transects with ID number highlighted were zigzagged; the red transects indicate where opportunistic observations where obtained). The high caribou density stratum included the area inside the blue outline. Elevation is not shown.



Results

Caribou on the transects, commonly reacted with flight when the helicopter flew by, however, frequently animals remained lying down or standing/grazing (Appendix 12, Figure 92). These animals typically looked at the helicopter but other overt reactions were not forthcoming. Hence movement was not the only key for locating animals present on a transect. The ability to spot the shape or colouring of a stationary caribou was necessary, regardless of the degree of camouflage against the varied backgrounds. The March 2005 snow cover conditions in the Central (Appendix 9a) and specifically the North region (Appendix 9b) made it clear that detecting caribou would have been difficult to impossible if it were not for the survey's low flight altitude, low speed, and narrow strip width. Current survey design promotes spotting caribou (Appendix 7). No dead caribou were observed.

At the flight altitude used, 15 m, "dead" ground is common on transects, i.e. terrain features prevent seeing the entire 300 metre strip width. Caribou may be missed because they are hidden from view. This is a source of negative bias and contributes to under estimating population size.

The correction calculation accounted for different correction factors for each stratum. Since no good method is available which could include the variance of a correction factor, the confidence intervals were instead calculated using a bootstrap method (Effron & Tibshirani 1993).

Akia-Maniitsoq estimated population size, Central Region

We observed a total of 554 caribou. The raw data (Appendix 4) gave an uncorrected pre-calving population estimate of ca 33,181 caribou, with densities of ca 1-3 caribou per sq km for the low and high-density strata respectively. After incorporating a correction for missed caribou (Cuyler et al. 2002), the pre-calving population size estimate for March 2005 became ca 35,807 (90% CI: 27,474 – 44,720), while densities remained basically unchanged (Table 2).

The survey of of Akia-Maniitsoq used 19 hours and 57 minutes of flying time. Weather conditions between the 14 and 16 March were excellent for strip visibility and caribou sightability. Snow cover, however, was patchy and could vary dramatically along an individual transect. This increased the difficulty in spotting caribou, and observers had to remain concentrated and focused while counting. Snow cover in the high-density stratum varied between 10 and 99%, while the typical range was 40 to 80%. As usual, the low-density stratum was almost totally covered in deep snow. Total number of Akia-Maniitsoq caribou seen per observer were as follows; 312 Christine Cuyler, 300 Rink Heinrich, 206 Johannes Egede. More caribou were observed on the left side of the helicopter than on the right, 336 and 218 respectively.

Kangerlussuaq-Sisimiut estimated population size, North Region

We observed a total of 1284 caribou. The raw data (Appendix 5) gave an uncorrected pre-calving population estimate of ca 87,244 caribou, with densities of ca 2-6 caribou per sq km for the low and high-density strata respectively. After incorporating a correction for missed caribou (Cuyler et al. 2002), the pre-calving population size estimate for March 2005 became ca 90,464 (90% CI: 70,276 – 113,613), while densities remained basically unchanged (Table 3).

The survey of Kangerlussuaq-Sisimiut used 26 hours and 38 minutes of flying time. This was greater than the number of hours used for the survey in the Central region, owing to the return helicopter ferry between Nuuk and Kangerlussuaq airports and the greater distances to refueling in the North region. Weather conditions on the first and second day of the survey were excellent, however, snow cover was often completely lacking, and typically patchy at best. Typical snow cover was 10-40%, although occassionally up to 99% . On the third and fourth days of the survey, a light dusting of new fall snow produced a "salt & pepper" background, against which the caribou were optimally camouflaged. Snowflurries and low cloud-fog further increased the difficulty in spotting caribou, by obscuring strip width visibility and often creating white-out conditions. These factors increased the difficulty in spotting caribou, and observers had to be extemely concentrated and focused while counting. Total number of Kangerlussuaq-Sisimiut caribou seen per observer were as follows; 701 Hans Mølgaard, 588 Christine Cuyler, 539 Rink Heinrich. More caribou were observed on the left side of the helicopter than on the right, 691 and 593 respectively.

Herd structure & recruitment

In March 2005, calf recruitment and number of bulls in the population were poor in both populations studied (Table 4, Appendices 4 & 5). Animals were widely spread throughout both regions, with a mean group size at ca 4.6 ±3.4 SD in the Kangerlussuaq-Sisimiut stock, and ca 4.3 ±2.9 SD in the Akia-Maniitsoq stock. Large congregations of animals were not common, and the largest numbered 17 caribou in both regions.

Table 2. *Survey information and preliminary raw and corrected population size estimates for Akia-Maniitsoq caribou, Central region, 14-16 March 2005.*

Parameter	High-density	Low-density	Totals
Area size	10,037 km^2	5,325 km^2	15,362 km^2
Number strips	39	15	54
Length of each strip	7.5 km	7.5 km	
Total strip width	2x 300 m	2x 300 m	
Area covered	175.5 km^2	67.5 km^2	243 km^2
Flight height	15 metres	15 metres	
Flight speed (km/hr)	46 to 65	46 to 65	
Total caribou seen (*n*)	485	69	554
Raw Density (caribou / km^2)*	2.76	1.02	1 to 3
Raw estimate herd size*	27,738	5,443	33,181
Corrected Density (caribou / km^2)**	**3.00**	**1.06**	**1 to 3**
Corrected estimate herd size**	**30,153**	**5,654**	**35,807**
90% Confidence Interval (CI)	**22,088 – 39,266**	**3,765 – 7,663**	**27,474 – 44,720**

* Herd size estimate from raw data with no correction for missed caribou.

** Herd size estimate after correction for missed caribou has been made.

Table 3. *Survey information and preliminary raw and corrected population size estimates for Kangerlussuaq-Sisimiut caribou, North region, 18-22 March 2005.*

Parameter	High-density Stratum	Low-density Stratum	Totals
Area size	8,000 km^2	18,000 km^2	26,000 km^2
Number strips	40	20	60
Length of each strip	7.5 km	7.5 km	
Total strip width	2x 300 m	2x 300 m	
Area covered	180 km^2	90 km^2	270 km^2
Flight height	15 metres	15 metres	
Flight speed (km/hr)	46 to 65	46 to 65	
Total caribou seen (*n*)	1090	194	1284
Raw Density (caribou / km^2)*	6.06	2.16	2 to 6
Raw estimate herd size*	48,444	38,800	87,244
Corrected Density (caribou / km^2)**	**6.22**	**2.26**	**+2 to +6**
Corrected estimate herd size**	**49,723**	**40,741**	**90,464**
90% Confidence Interval (CI)	**41,833 – 58,470**	**22,263 – 62,251**	**70,276 – 113,613**

* From raw data with no correction for missed caribou.

** After correction for missed caribou has been made.

Table 4. Herd Structure for two caribou herds in West Greenland, March 2005.

Parameter	Akia-Maniitsoq Caribou Population	Kangerlussuaq-Sisimiut Caribou Population
Region (Hunting area)	Central (3)	North (2)
Time period	14-16 March 2005	18-22 March 2005
Method	Helicopter	Helicopter
Total sexed & aged (*n*)	705	745
Number of groups observed	163	161
Average group size	4.33 ± 2.91 SD	4.63 ± 3.38 SD
Maximum group size	17	17
Minimum group size	1	1
Bull (> 1 year)	187 (26.52%)	163 (21.9%)
Cow (> 1 year)	419 (59.43%)	501 (67.3%)
Calf from 2004	99 (14.04%)	81 (10.9%)
Recruitment (calf/100cow)	24	16.2
Bull to Cow ratio	0.45	0.33

Discussion

Kangerlussuaq-Sisimiut population

The corrected pre-calving March 2005 Kangerlussuaq-Sisimiut population estimate is ca 90,464 caribou (90% CI : 70,276 – 113,614). This is best considered a conservative estimate since a negative bias of caribou missed remains, owing to this year's weather conditions, patchy snow cover, "salt & pepper" backgrounds, and "dead" ground. This estimate is almost double the 2000 survey estimate and is greater than any previous estimate for this herd. An interpretation of population trend from this result is difficult since methods differed. The present survey better reflects true animal abundance in 2005.

The stocking density is now over six caribou per sq km, almost a doubling since the 2000 survey. Given the large population size, it was not unexpected that mean group size increased (Figure 6). Large aggregations of caribou, however, were not common and the maximum group size was unchanged from the survey in 2000. Meanwhile, the percentage and recruitment of calves into the population is the lowest observed (Figure 7, 8). The percentage of calves is similar to the natural mortality value. It is possible that this population is approaching its theoretical carrying capacity where births equal deaths, i.e. production equals zero. A population at carrying capacity will not be able to provide a sustainable optimal yield for annual harvest.

Table 5. *Greenland caribou population estimates, harvest quotas, reported harvest and the percentage by which the quota was filled.*

Year	Estimate of total caribou in Greenland	Quota	Reported Harvest (Piniarneq) **	Amount of quota filled
1995	ca 18,000	2,000	1,398	69.9%
1996	ca 22,000	2,600	2,048	78.8%
1997		3,111	2,755	88.6%
1998		3,680	3,692	100.3%
1999		4,050	3,957	97.7%
2000		13,600	9,671	71.1%
2001	ca 140,000	24,300	13,490	55.5%
2002		36,150*	16,910	52.3%
2003		**Open**	18,851	-
2004		**Open**	Not yet available	-

* The 2002 harvest quota was originally set at 32,150 caribou; however, the number of licences permitted exceeded that number by 4,000.

** Piniarneq records are from the Directorate for Fisheries & Hunting, P.O. Box 269, 3900 - Nuuk, Greenland.

Given that the North region is ca 26,000 sq km, if the recommended stocking density of 1.2 caribou per sq km was attained, then an appropriate population size might be ca 31,200 caribou. The 2000 population estimate for the North region exceeded this by almost 20,500 animals, and the 2005 estimate exceeds it by almost 60,000 caribou. Although annual harvest results per population are unavailable, the total numbers of caribou harvested in Greenland (Table 5) are low relative to the numbers required for population reduction even in just the North region. Therefore, despite the large quotas in 2000-2001 followed by open harvests in 2002/03/04, hunting has not been sufficient to halt growth or reduce the Kangerlussuaq-Sisimiut herd size.

Akia-Maniitsoq population

The Akia-Maniitsoq stock situation is slightly different. The corrected pre-calving March 2005 Akia-Maniitsoq population estimate is ca 35,807 caribou (90% CI : 27,474 – 44,720). This is also best considered a conservative estimate since a negative bias of caribou missed remains, owing to this year's patchy snow cover and "dead" ground. This estimate is ca 10,000 animals less than the 2001 survey estimate, but is still a large number for this herd. The only difference between the 2001 and 2005 survey was the addition of seven transects, which could not be flown in 2001 owing to financial constraints. The additional transects in 2005 served only to reduce the variance and did not affect the population size estimate. Since methods between the surveys of 2001 and 2005 did not differ, the present results may reflect a true decrease in animal abundance over the past four years. When the two estimates are compared the result is a $P = 0.12$. This indicates a 12% probability that the 2005 estimate was smaller by chance.

Given that the Central region is ca 15,362 sq km, if the recommended stocking density of 1.2 caribou per sq km was attained, then a suitable population size might be ca 18,434 caribou. The 2001 population estimate for the Central region exceeded this by almost 28,000 animals, and the 2005 estimate exceeds it by almost 17,500 caribou. The Akia-Maniitsoq stock density dropped since 2001, however, it remains too high in 2005. In 2001, it was four-times the recommended target and in 2005 is three-times. Since hunting had no clear impact on the Kangerlussuaq-Sisimiut population, the apparent stock reduction that has occurred in Akia-Maniitsoq is not automatically assumed due to hunting. Rather it could be an expression of greatly increased natural mortality due to overstocking. The latter is supported by the poor calf recruitment observed in March 2005.

Density-dependent effects

Density-dependent effects are the result of intraspecific competition, i.e. between individuals in the same stock. Direct effects typically increase mortality, while delayed effects affect growth and fecundity. With increasing densities, severe weather events can have additional effects on recruitment, with consequences for population stability (Skogland 1985). In 2001, although caribou densities were as high as 3-4 per sq km, there was no evidence of dramatic density effects in any of the west-coast populations. Still the calf percentage was considered low in two populations, the Akia-Maniitsoq (Central region) and Ameralik (region South). In contrast, the current March 2005 surveys strongly suggest that density dependant factors now play a major role in caribou population dynamics in the two stocks examined. Other stocks in West Greenland may be experiencing similar problems.

Recruitment

The Akia-Maniitsoq (Central region) had a late winter calf percentage of ca 14% and a recruitment of only 24 calves per 100 cows. The Kangerlussuaq-Sisimiut (North region) stock had a calf percentage of ca 11% and a recruitment of only about 16 calves per 100 cows. The results for both stocks are low compared to herds elsewhere. Studies from North America and Scandinavia report late winter recruitments of 41 calves per 100 cows (Fancy Whitten & Russell 1994), 20 calves per 100 cows (Dzus 1999) and 22 calves per 100 cows (Parker 1972), and some of these populations typically have predators. Further a comparison to the Southampton Island herd, which like Greenland has no predators, shows late winter recruitments varying between 22 and 77 calves per 100 cows (Heard & Ouellet 1994). This suggests that the current Kangerlussuaq-Sisimiut caribou herd late winter recruitment is low, while the Akia-Maniitsoq recruitment is tending in the same direction.

The poor calf recruitment strongly suggests an elevated natural mortality among calves, and a decreased fecundity of adult females. Independent of climate and genetics, caribou calf mortality increases with high population density and grazing pressure (Valkenburg et al. 2000). Further, calf recruitment is low or variable where winter ranges are overgrazed and hard or deep snow is common (Heggberget et al. 2002). At Kangerlussuaq snow is ruled out as a cause of decreased recruitment, because hard or deep snow is almost never a problem in the dry steppe climate of the North region, which is where caribou density is highest. Knowledge on possible changes in female fecundity is not available, however, increased calf mortality may occur when animal densities are high. Thing & Clausen (1980) suggested high caribou density increased faeces contamination (bacteria and parasites) of the feeding areas and caused the observed high mortality in 2-3 month old calves of the Kangerlussuaq-Sisimiut stock in 1977/78. At calving in June 2004, 20 to 30 % of newborn calves were observed with diarrhoea (P. Aastrup pers comm.). Death by dehydration typically follows.

The low recruitment in both populations shows that little replacement is occurring, i.e. there are few individuals in the next generation. This situation is cause for concern, because it could contribute to a crash in abundance, specifically if adverse and widespread stochastic events occur.

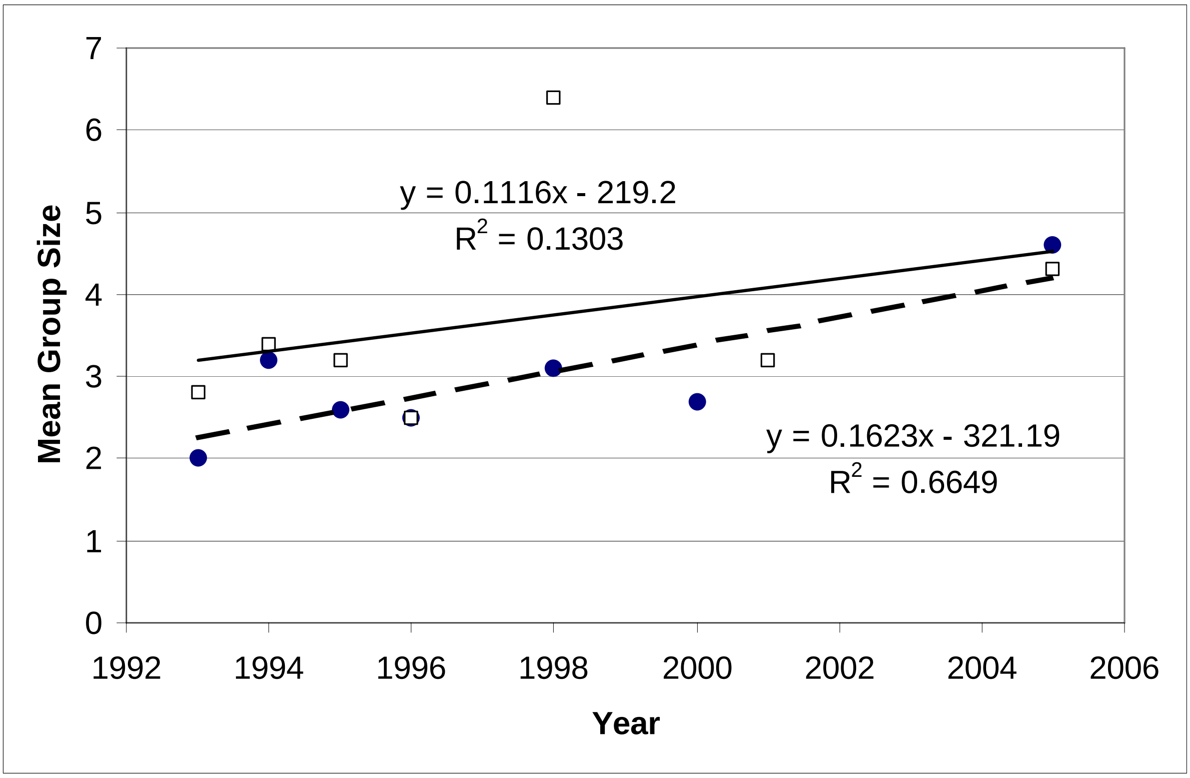


Figure 6. Changes in mean group size since 1992 in two West Greenland stocks; Kangerlussuaq-Sisimiut stock (●, - - -) (p = 0.03), and Akia-Maniitsoq stock (□, ––) (p = 0.43); linear regression lines with r^2 values.

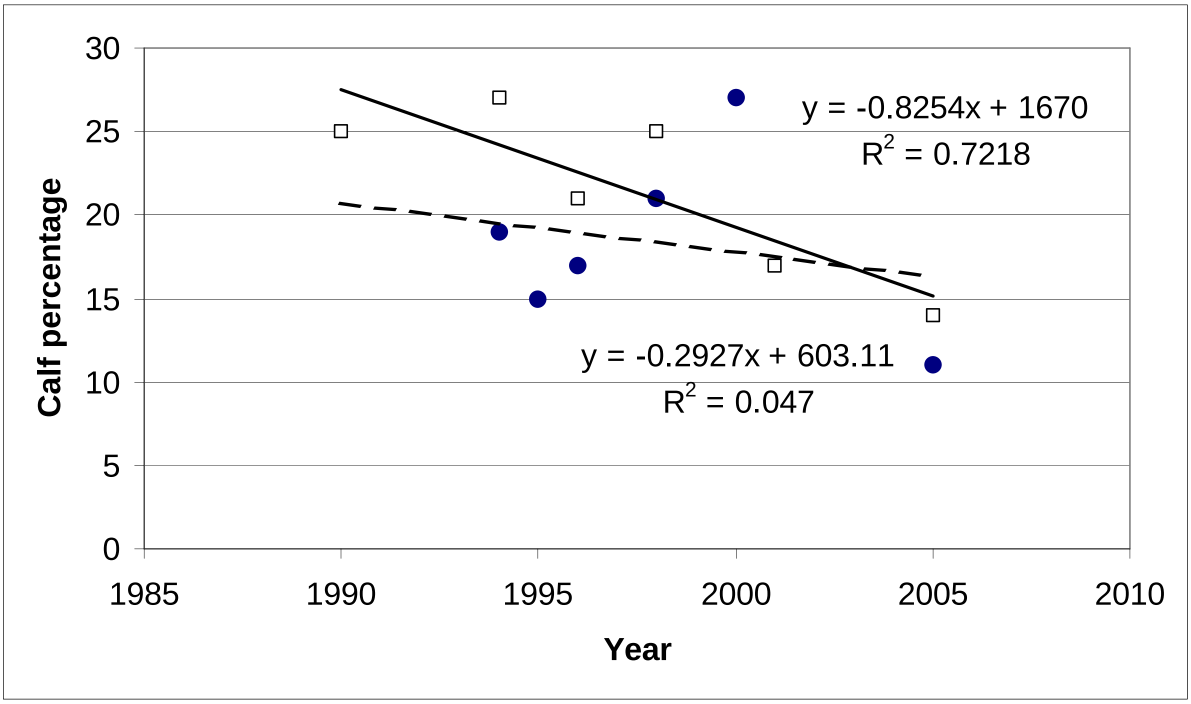


Figure 7. Changes in calf percentage since 1990 in two West Greenland stocks, Kangerlussuaq-Sisimiut stock (●, - - -) (p = 0.68), and Akia-Maniitsoq stock (□, —) (p = 0.03); linear regression lines with r^2 values.

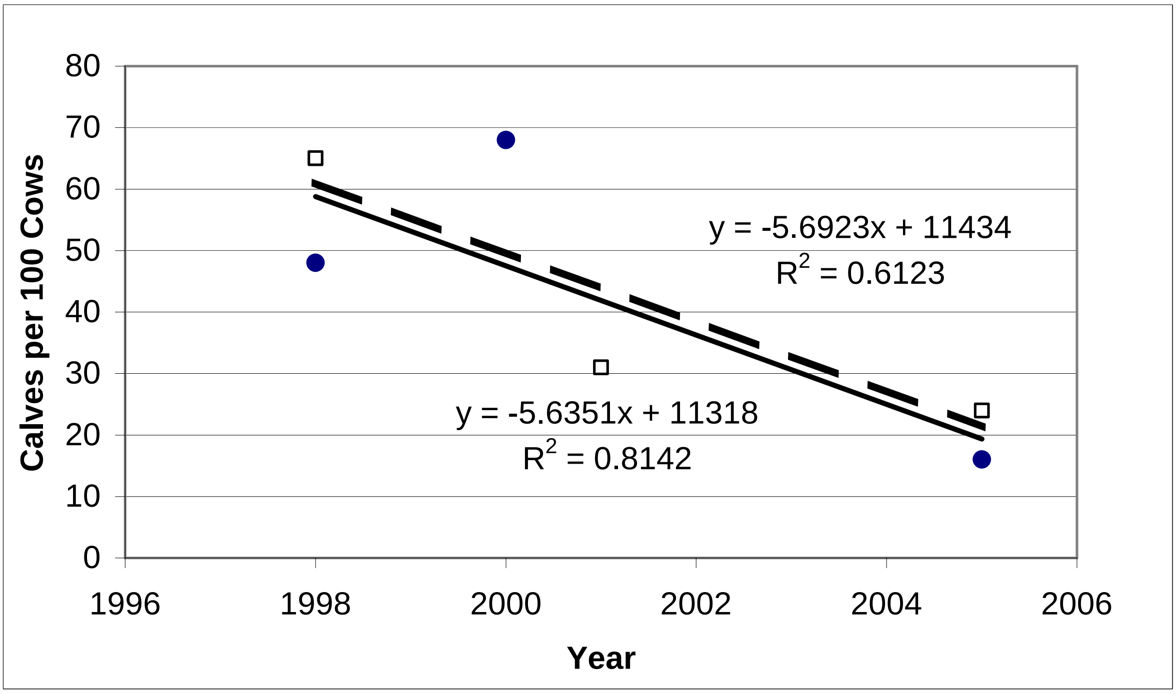


Figure 8. Changes in late winter recruitment (calves per 100 cows) in two West Greenland stocks, Kangerlussuaq-Sisimiut stock (●, - - -) (p = 0.43), and Akia-Maniitsoq stock (□, —) (p = 0.28) ; linear regression lines with r^2 values.

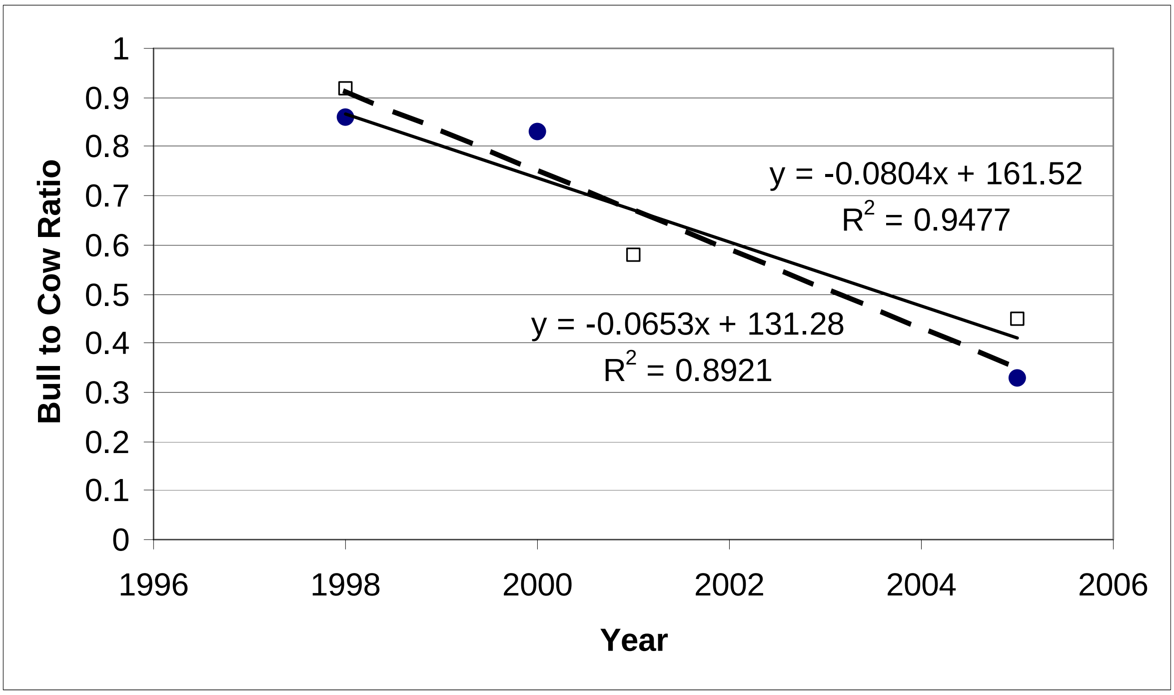


Figure 9. Changes in the Bull to Cow ratio in two West Greenland stocks, Kangerlussuaq-Sisimiut stock (●, - - -) (p = 0.15), and Akia-Maniitsoq stock (□, —) (p = 0.21) ; linear regression lines with r^2 values.

Bull to Cow ratio

Barboza et al. (2004) suggested that population density and environmental conditions may cause higher rates of post-mating mortality among male caribou and reindeer (*R.t. tarandus*), since mating compromises reindeer survival owing to reduced food intake, body reserves and condition, which are not recovered over the following winter even if winter food resources are unlimited. This makes our low late winter 2005 bull to cow ratios cause for concern. In both stocks the 2005 ratios were the lowest in seven years (Figure 9), 0.45 in Akia-Maniitsoq and 0.33 in Kangerlussuaq-Sisimiut. Male skewed harvesting, although common in Greenland (Loison et al. 2000), is not suspected as the cause, because for about the past decade the number of animals removed from each stock has been relatively insignificant to that population's size. We hypothesize that the abnormally high stocking densities over the past several years have undermined range condition or led to forage limitation. Perhaps prior to the rut some bulls are unable, owing to steep competition for resources, to attain sufficient body condition to maintain them through the rut and subsequent winter and male natural mortality rises.

Although P-values were not often significant, the steady declines in both calf recruitment and bull to cow ratios are expected to continue since most of the r^2 values are approaching 1 (Figures. 7, 8 and 9), which indicates good predictive power to the regression lines.

Annual natural mortality

Adult natural mortality for caribou in five North American herds without natural predators is 4-6% annually (Bergerud 1967, 1971, Skoog 1968, Kelsall 1968), which corresponds to a life expectancy of 17 to 25 years. Adult annual natural mortality has been ca 8% on Southampton Island (NWT, Canada), which is also without predators (Heard & Ouellet 1994), and Thing (1982) suggested a natural mortality of 7% for adult caribou of the North region in West Greenland. Actual natural mortality values for West Greenland caribou in the 1990's appeared around 8-10%, given the general life expectancy of 10 to 12 years found in Loison et al. (2000) and Cuyler & Østergaard (2005).

Stochastic events and density dependent effects notwithstanding, using a natural mortality of 8-10% and the current population estimates the Akia-Maniitsoq herd, equates to an expected natural mortality of between ca 2,200 and 4,500 caribou annually in the Central region. Similarly, the expected natural mortality is between ca 5,600 and 11,400 caribou each year for the Kangerlussuaq-Sisimiut population in the North region.

Management implications

The current population estimates, densities, herd structures and calf recruitment make it clear that the 2002 advised density target, i.e. 1.2 caribou per sq km, was not achieved for either population studied. Although our knowledge of the carrying capacity on West Greenland ranges is imperfect, over-abundance of caribou on the range may be a current problem, which may soon become an acute problem. Unfortunately, it is unknown how much longer the present range can continue to support the current caribou numbers. If the herds are allowed to continue status quo or increase further there is a clear risk of lasting damage to ranges. If the ranges are destroyed, caribou stocks can be expected to crash.

Modeling suggests that the amplitude of population fluctuations is related to the population growth rate (Messier et. al. 1988), i.e. the potential for a severe crash is accentuated if a stock grows quickly. Although population sizes are not readily comparable owing to differing survey design, it remains that caribou stocks in West Greenland grew quickly (Table 6). This suggests that annual total catches since 1995 (following the 2-year hunting ban) had no regulatory effect on caribou stocks in West Greenland. Increasing total catch now, even in those herds whose size are decreasing, may reduce overgrazing (or potential) and its dire consequences for caribou stocks. Although catches large enough to impact current stock sizes may not be possible, if the majority of animals taken are females then growth may be reduced. Regardless of increased total catches today, it may be too late to avert stock crashes. It is possible that one or more of West Greenland's caribou populations may collapse within the next decade.

Global warming is the "joker" concerning the future of West Greenland's caribou stocks, and make clear predictions about herd trends impossible. Will the resulting climate changes from global warming alter caribou habitat conditions for the better or worse? At present, two of our West Greenland caribou stocks appear ready for a crash, however, this event may be delayed. Climate changes could alter vegetation type, quality, quantity and availability for the caribou. In a positive direction, winters might be shorter with less snow and perhaps punctuated by mid-winter thaws removing snow cover from the range. There might also be a decrease in the extent, frequency and severity of winter icing events, which can effectively prevent caribou from reaching food resources. Summers might be long, cool and wet, which promotes lichen growth and keeps insect pests in check. If summers become hot and dry, then the result may be caribou with poor summer/autumn body condition, owing to the increased insect harassement, which causes more caribou movement and less feeding. With increased summer temperatures Greenland may also witness a growth in bacterial diseases and parasite loads among the caribou. Many other effects may be possible, and studies on caribou and their range will be important in understanding where our herds are headed.

Too many caribou can reduce the quantity and quality of their range, resulting in among other things decreased body size and condition. It is important to prevent overpopulation and subsequent range destruction /deterioration/degradation in order to preserve the foundation of vegetation on which a healthy productive caribou/reindeer population depends.

Acknowledgements

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Table 6. Winter population estimates and minimum counts of wild caribou / reindeer in Greenland. All population size estimates are approximate[1].

Caribou / Reindeer Population	**Region No.**	**Region Name**	**1977 /78**	**1993**	**1994**	**1995**	**1996**	**1999**	**2000**	**2001**	**2002**	**2005**
Inglefield Land	10	-	-	-		100		2,260	-	-	-	-
Olrik Fjord	9	.	-	-		-				38*	-	-
Nuussuaq Halvø	8	-	170	-		400				400	1.164*	-
Naternaq	1	Naternaq	100	80		271				-	-	-
Kangerlussuaq-Sisimiut	2	North	17,900	3,788	7,727	6,196	10,869		51,600**	-	-	90,464**
Akia-Maniitsoq	3	Central	5,300	3,506	3,080	6,408	6,806		-	46,236	-	35,807
Ameralik	4	South	-	1,341	1,458	4,553	4,458+		-	31,880	-	-
Qeqertarsuatsiaat	5	South	-						-	5,372	-	-
Qassit	6	Paamiut	-	-		-			196*	-	-	-
Neria	7	Paamiut	-	-	181	407			1,600 (332*)	-		-
Total Estimate for Greenland	-	-	-	**9,000** (6865–10559)	**13,000** (10105–15530)	**18,000** (14761–21558)	**ca 22,000** (19581–25027)		-	**ca 140,000**[2]	-	-

[1]Estimates from 2000 to 2005 were obtained using survey methods and design unlike those employed from 1993 to 1999. Therefore herd size differences between these two time periods are not assumed readily comparable.

[2] Rough sum of population estimates from 1999, 2000 and 2001.

*Minimum counts.

**Kangerlussuaq-Sisimiut estimates from 2000 and 2005 were obtained using somewhat dissimilar methods, i.e. the 2005 survey reduced flight altitude by 85 m, speed by ca 45 km/hr, and strip width by 400 m. The two estimates are therefore not assumed readily comparable and should not be interpreted as indicating population trend for this herd.

Sources: Ydeman & Pedersen 1999, Linnell et al. 1999, Landa et al. 2000, Cuyler et al. 2002, 2003, 2004, and current study.

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Appendix 1

Region Stratification & Transect Allocation

How many transects are needed?

One of the most important questions that have to be answered before undertaking any survey is whether the survey will yield data of a sufficient quality to answer the question that the survey attempts to answer; animal abundance. A related question is the choice of sample size. In a helicopter survey, where flight hours in Greenland are very expensive, this question becomes very important.

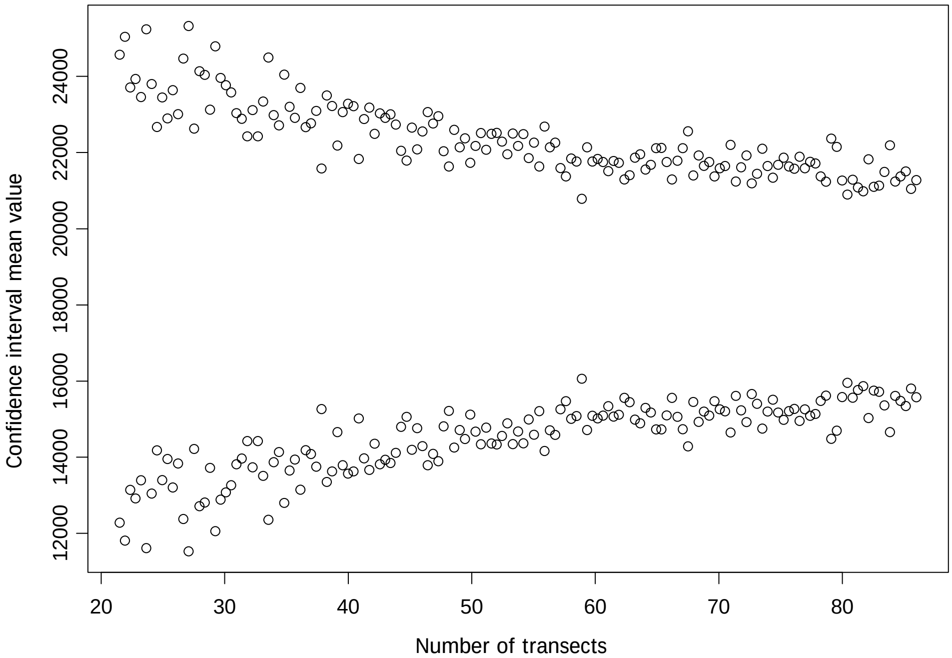
An idea of the expected variance is necessary. In flight surveys the variance is intimately related to the density of animals. The prior information available before the surveys was relative densities from a previous survey in 1996 and densities found in the North region in 2000. The assumption made was that although the 1996 surveys used a radically different methodology, the relative densities would remain fairly constant. Implicit in that assumption is the expectation that the caribou populations in all regions have had similar growth rates since 1996 despite that they form clearly distinct populations with different demographics.

A simulation experiment was performed in the following fashion. The highest density area in the 1996 survey was the high-density area of the North region, the density of the other areas was known as a fraction of the density of that high-density area. For each simulated transect the number seen is found as follows. A random transect from the high-density area in the North region is chosen and the number seen there is called "s". If r is the relative density of the area in question and w is the relative width of the transects then a number seen can be simulated as a binomial:

$$Binomial(s, r \cdot w)$$

Once a simulation was done, the resulting data was analyzed using standard parametric methods, and a confidence interval found. The procedure was repeated for different total numbers of transects. The data was then plotted by taking all the confidence intervals, centering these on their common mean and plotting them against the total number of transects (Figure 10).

Figure 10. How many transect lines needed for a relatively accurate and precise survey of the Central region? Simulation of confidence interval mean values versus the number of transects used.



From the graph it is obvious that an effort smaller than 40 lines will result in a wide confidence interval, whereas a number larger than 60 will be a waste of resources. Note that the picture here is slightly misleading since it takes into account only the width of the confidence interval around the grand mean of the estimates. In reality the means will jump around less for higher sample sizes. For economic reasons the final number of transect lines in 2005 was set to 54 for the Akia-Maniitsoq herd in the Central region, while 60 transects were again applied for the Kangerlussuaq-Sisimiut herd in the North region.

Transect allocation

Since the Central region is divided into two strata with different expected densities, transect allocation must be decided. Here a simple mathematical method was used for allocating transects to each strata. The standard method for allocation of transects to strata is to allocate proportional to the product of the area and the expected standard deviation of each strata.

If : A_i is the area of strata i

d_i is the expected density of strata i

then the best allocation is proportional to

$$A_i \cdot d_i^{\alpha}$$

where: $\alpha = 0.5$ corresponds to the square root of the expected density.

Note that it is sufficient to have the expected relative densities and areas. For areas {1,..,i} the proportions of transects allocated to area 1 will be.

$$p_1 = \frac{A_1 \cdot d_1^{\alpha}}{\sum_i A_i \cdot d_i^{\alpha}} = \frac{1}{\sum_i \frac{A_i \cdot d_i^{\alpha}}{A_1 \cdot d_1^{\alpha}}} = \frac{1}{\sum_i \frac{A_i}{A_1} \cdot \frac{d_i^{\alpha}}{d_1^{\alpha}}} = \frac{1}{\sum_i \left(\frac{A_i}{A_1}\right) \cdot \left(\frac{d_i}{d_1}\right)^{\alpha}}$$

There are several ways of choosing α. For animals that tend to be in groups the question centres around whether they tend to increase the group size when the density is higher. If the group size is the same regardless of density then α = 0.5. If on the other hand the group size tends to go up with higher density without the number of groups changing then α = 1. In this case we chose α = 0.75 as a compromise solution.

The allocation assumed that the relative densities remained unchanged since last survey of 1996. The stratification was not the same as in the last survey, but was altered based on the observed densities in 1996. The Central and North regions were divided into two strata, a high and low-density strata. On the basis of the above mentioned formulas, in 2005 the Central region was allocated 15 transects to the low-density area and 39 transects to the high-density area. Similarly the North region was allocated 20 transects to the low-density area and 40 transects to the high-density area.

Appendix 2

Survey field method and statistical design

Accuracy equates to the population size calculated being close to the true value. Bias, which makes the calculated population size depart from reality, results in inaccuracy. There can be bias in your counting, sampling design or even analysis. Precision is the measure of variation in the numbers of caribou on each of the transects. Poor precision can result from sampling errors, e.g. if group size and distribution were highly variable within a stratum.

Field methods

Reducing negative bias: Sightability of caribou on transect

To reduce the negative bias associated with violation of the assumption that all caribou within the strip are observed, the following survey field methods were used.

Narrow strip width, 300x2 metres,
Slow flying speed, ca 46-65 kilometre/hour,
Low altitudes, 15 metres,
Sun typically behind observers,
Short transect length, 7.5 kilometres (promoted concentration and reduced fatigue),
Statistical correction for missed caribou.

Statistical design

Caribou population estimates can be calculated as follows:

For each stratum we have:

$$\hat{N}_j = A_j \cdot \frac{\sum_i y_i}{\sum_i A_i} = \frac{A_j}{\bar{A}} \cdot \bar{y} \qquad (0.1)$$

Where

$\hat{N}_j$	is the estimated total in the j^{th} strata
y_i	is the total number of caribou observed in strip i
A_j	is the total area of strata j
A_i	is the area of strip i
$\bar{A}$	is the mean area of the strips in the stratum

Because the area of each strip is constant the calculation of variance is

$$Var(\hat{N}_j) = Var(\frac{A_j}{\overline{A}} \cdot \overline{y}) =$$

$$\left(\frac{A_j}{\overline{A}}\right)^2 Var(\overline{y}) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot Var(\frac{\sum_i y_i}{n}) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n} Var(\sum_i y_i) =$$

$$\left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n^2} Var(\sum_i y_i) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{1}{n^2} (n \cdot Var(y_i)) = \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{Var(y_i)}{n}$$

$$\hat{V}ar(y_i) = s^2 = \frac{1}{n-1} \sum_i (y_i - \overline{y})^2$$

Since the total number of caribou in the area is the sum of the totals in each stratum the variance of the total will be the sum of the variances in the strata.

$$\hat{N} = \sum_j \frac{A_j}{\overline{A}} \cdot \overline{y}_j$$

$$Var(\hat{N}) = \sum_j \left(\frac{A_j}{\overline{A}}\right)^2 \cdot \frac{Var(y_i)}{n}$$

Appendix 3

Increasing the accuracy of aerial counts of caribou in western Greenland.

Most aerial surveys of animal abundance are negatively biased because animals within the sample unit are overlooked by observers. Various doublecount methods have been developed to generate survey specific correction factors. However, these methods require that observations can be attributed to specific individuals or groups, which is not always possible. We present a simple method for generating a minimum estimate of the number of overlooked animals based on the total number of animals seen by double observers on one side of the aircraft. In addition, we describe aspects of survey design that have been used in caribou *Rangifer tarandus* surveys in West Greenland to further reduce bias.

The extent to which animals are overlooked can be influenced by many factors such as aircraft design, flying speed, flight height, light conditions, vegetation density, topographic complexity, and observer experience/fatigue (Caughley 1974, Samuel et al. 1987, Aastrup & Mosbech 1993). Early attempts to correct for this bias focused on determining a factor from a series of controlled trials, and using this as a blanket correction factor for all further surveys (Caughley 1974, Caughley et al. 1976, Samuel et al. 1987, Pollock & Kendall 1987, Aastrup & Mosbech 1993). However, because conditions vary from survey to survey there have been attempts to develop survey-specific correction factors, especially using the doublecount methodology (Pollock & Kendall 1987, Graham & Bell 1989, Rivest et al. 1995). In this process, at least one side of the aircraft has two observers. Using the numbers of animals or groups seen by the first observer only, the second observer only, or by both observers it is possible to apply capture-mark-recapture methodology to calculate the number of animals seen by neither observer (Pollock & Kendall 1987). However, this requires that observations from the two observers can be attributed specifically to each animal or group observed. While such results may be achieved using double-track tape recorders (Marsh & Sinclair 1989) or GPS/data logger technology, there are always situations whereby technology fails, is unavailable or cannot be applied practically. We present an extension of the normal doublecount statistics to estimate the correction factor for the proportion of animals unseen using the total number of animals counted by each observer within a given sample strip. In many ways this is similar to the aims of Caughley & Grice (1982), but is designed for species that occur at a higher density.

Accounting for overlooked animals

In the cases where there are more than one observer in one side of the aircraft and it is possible to know which animals have been seen or not seen by each observer, it is possible to estimate the probability that a visible animal has been observed. The method is thoroughly discussed in Pollock & Kendall (1987) and will be slightly elaborated upon here. We will use the following nomenclature similar to the one used by Graham & Bell (1989).

B	is the number of animals observed by both observers
S_f	is the number of animals observed by the front seat observer only
S_r	is the number of animals seen by the rear seat observer only
M	is the number of animals not seen by either observer
p_f	is the probability that a visible animal is seen by the front seat observer
p_r	is the probability that a visible animal is seen by the rear seat observer
N	is the total number of visible animals in the transects

Then $N = S_f + S_r + B + M$

In a conventional doublecount setup where animals or groups can be individually identified for comparison between observers the following procedure is often used:

B can be estimated as $E(B) = p_f \cdot p_r \cdot N$

Therefore $N = \dfrac{E(B)}{p_f \cdot p_r}$

In the same manner S_f can be estimated as

$$E(S_f) = p_f \cdot (1 - p_r) \cdot N$$

By substitution

$$E(S_f) = p_f \cdot (1 - p_r) \cdot \frac{E(B)}{p_f \cdot p_r}$$

$$E(S_f) = (1 - p_r) \cdot \frac{E(B)}{p_r}$$

$$E(S_f) \cdot p_r = E(B) - E(B) \cdot p_r$$

$$(E(S_f) + E(B)) \cdot p_r = E(B)$$

$$p_r = \frac{E(B)}{E(B) + E(S_f)}$$

In the same manner p_f can be estimated as

$$p_f = \frac{E(B)}{E(B)+E(S_r)}$$

Thereby the proportion of animals overlooked by both the front and the rear seat observer is

$$(1-p_f)\cdot(1-p_r)$$

Therefore, the number of observed animals in the left side of the helicopter should be multiplied with

$$\frac{1}{1-(1-p_f)\cdot(1-p_r)} = \frac{1}{1-(1-\frac{B}{B+S_r})\cdot(1-\frac{B}{B+S_f})} = \frac{(B+S_f)\cdot(B+S_r)}{B\cdot(B+S_f+S_r)}$$

or equivalently

$$\hat{N} = (B+S_f+S_r)\cdot\frac{(B+S_f)\cdot(B+S_r)}{B\cdot(B+S_f+S_r)} = \frac{(B+S_f)\cdot(B+S_r)}{B}$$

And, under the assumption that the left and right rear seat observers have the same probability of observing a visible animal, the right side observations should be multiplied by

$$\frac{1}{p_r} = \frac{B+S_f}{B}$$

This method does not take into account the variance in the estimates of p_f and p_r. The easiest way to find confidence intervals is to use a bootstrap procedure (Effron & Tibshirani 1993).

The estimates of p_f and p_r are equivalent to the Petersen estimate. Although this estimate is biased, the bias can be eliminated using Chapman's correction.

$$\hat{N}_{left} = \frac{(B+S_f+1)\cdot(B+S_r+1)}{B+1} - 1 \quad \text{(Graham \& Bell 1989)}$$

Then $\frac{\hat{N}}{S_r+B}$ will be an estimate of $\frac{1}{p_r}$

Hence the estimate of the number of animals on the right side of the aircraft is

$$\hat{N}_{right} = S_{right} \cdot \frac{(B+S_f+1)\cdot(B+S_r+1)-(B+1)}{(B+1)\cdot(S_r+B)}$$

However, if we don’t know which specific animals or groups have been seen by each observer but have the total number of animals observed within each strip for each observer, then we can calculate maximum values for p_f and p_r

If for each strip i

f_i is the number of animals seen by the observer in the front seat

r_i is the number of animals seen by the rear seat observer

Then we can define

$$B^* = \sum_i Min(f_i, r_i)$$
$$S_f^* = \sum_i Max(0, f_i - r_i)$$
$$S_r^* = \sum_i Max(0, r_i - f_i)$$

and observe that

$$B^* \geq p_f \cdot p_r \cdot N$$
$$S_f^* \leq p_f \cdot (1-p_r) \cdot N$$
$$S_r^* \leq p_r \cdot (1-p_f) \cdot N$$

leading to

$$N \leq \frac{B^*}{p_f \cdot p_r}$$

and

$$S_f^* \leq p_f \cdot (1-p_r) \cdot N \leq p_f \cdot (1-p_r) \cdot \frac{B^*}{p_f \cdot p_r}$$

$$p_r \leq \frac{B^*}{B^* + S_f^*}$$

Similarly

$$p_f \leq \frac{B^*}{B^* + S_r^*}$$

Since we here are dealing with maximum values of p_f and p_r the corresponding values for overlooked animals will be minimum values. Accordingly the corrected values for the number of animals seen will still be negatively biased. As this methodology gives a lower bound of the probability of observing a visible animal it is instructive to simulate some observations in order to gauge the effectiveness of the method.

Since we are assuming that for each transect line the number seen by both observers is equal to the lowest number seen, it would be reasonable to assume that the method works best for small observation numbers and large observation probabilities. This assumption can be tested using a simulation study. In this simulation a number of virtual surveys were set up, each with 100 transect strips. For each assumed level of detection probability (0.6; 0.7; 0.8; 0.9) a mean number of animals per strip was chosen between 1 and 10. The number of animals on each transect strip was chosen as a Poisson random variable. The number of animals seen by each observer was then chosen as a binomial random variable. The resulting estimates of the sighting probabilities were then plotted against the mean number of animals per strip. As expected (Figure A1) the estimated detection probabilities tended to be too high, particularly when the number of animals per strip is high.

Reducing bias through survey design

The overriding concern with the survey design has been to minimise the number of overlooked animals by flying closer to the ground and concentrating the effort in a narrow strip close to the aircraft. In addition, observer fatigue was minimised by flying many short transect strips, rather than fewer longer strips. It is possible to evaluate the effectiveness of the different experimental protocols by comparing p_f and p_r between years. In addition, it is instructive to see how large a difference accounting for overlooked animals makes in each case (Table 7).

In the 2000 survey (with the higher flight altitude and wider strip) for the Kangerlussuaq-Sisimiut region there was still a large bias that needed to be corrected. In contrast, the 2001 surveys (lower altitude, narrower strip) in the other three regions resulted in a much smaller bias (Table 7).

Discussion

The above example clearly supports a wealth of previous studies and demonstrates that failing to take overlooked animals into account during aerial surveys will produce an underestimate (inaccurate) of true population size. While we appear to have been able to reduce bias through improved survey design (lower flight altitude, narrower strip) our methodology provides a simple procedure to establish a survey specific correction factor provided that double observers are available for at least one side of the aircraft. Our approach does not require that observations by the double observers can be attributed to specific groups and is therefore suitable to situations where the technology for such cross-referencing does not exist, or where it is difficult to attribute animals to specific groups.

When our experience is taken together with the experience reported in the scientific literature it would appear that the aerial surveys performed in the 1993-96 period (Linnell et al. 2000) produced severe underestimates of population size. The use of a fixed-wing aircraft rather than helicopter, higher flying speeds and altitudes, wider strip widths and longer transects are all likely to increase the proportion of overlooked animals. In addition their analysis failed to correct for uncounted animals. The resulting conflict over caribou management in Greenland (Linnell et al. 2000) shows the importance of addressing bias in aerial surveys.

Even after applying our correction methodology, the resulting estimate is still an underestimate of true population size. This is because (1) we assume maximum values of p_f and p_r and (2) there will always be animals that are present in the strip but are hidden from both observers by vegetation or topography, i.e. they have a null sighting probability. This effect is most likely to be pronounced in forested areas (Samuel et al. 1987, Rivest et al. 1998). Even though our surveys all occurred on treeless tundra, the topographic complexity may have obscured some caribou from both observers, especially at the lower flying altitudes. The statistical approach presented by Rivest et al. (1998) offers one potential approach to account for the issue should further experiments show that the effect is substantial.

Table 7. Results of the caribou surveys conducted in four regions of western Greenland (2000-2001), highlighting the differences in sighting probability by the double observers, the effect that correcting for visibility bias has on the estimated population size and the effect of reducing flying height and strip width.

Area	Kangerlussuaq-Sisimiut	Akia	Ameralik	Qeqertarsuatsiaat
Altitude	100 m	17 m	17 m	17 m
Strip width	1,000 m	600 m	600 m	600 m
P_f	0.94	0.89	0.88	0.89
P_r	0.68	0.85	0.92	0.82
80% CI uncorrected	36,000-52,800	35,000-51,700	23,300-37,900	2,800-7,900
80% CI corrected	42,700-61,500	37,000-55,800	24,700-39,300	2,900-8,200

Data taken from Cuyler et al. 2002, 2003.

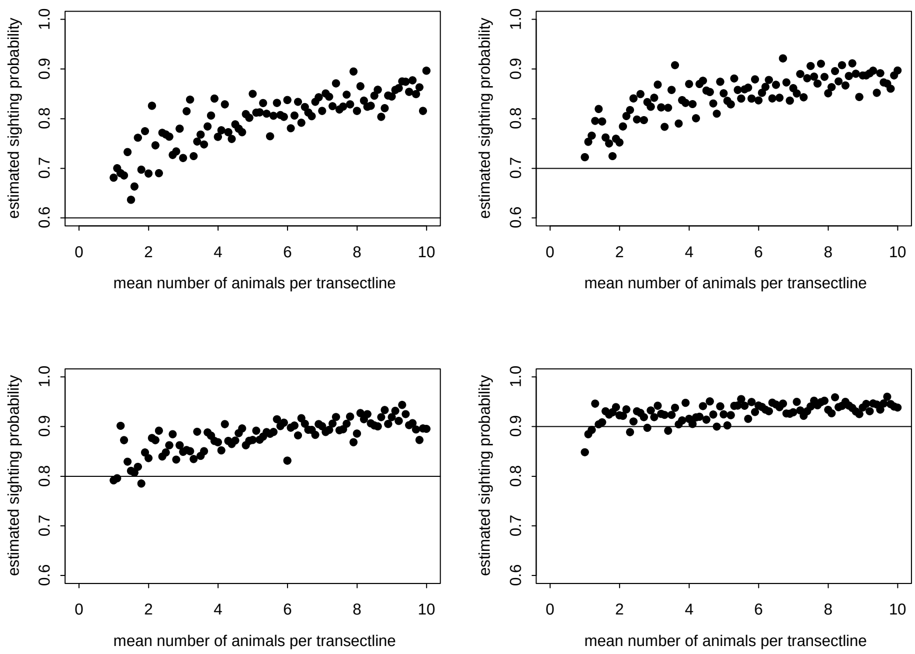


Figure 11. Simulations of the effects of number of animals encountered per transect strip on the estimated sighting probability (bias adjustment) at four different levels of detection probability (the horizontal line at 0.6, 0.7, 0.8 and 0.9).

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Appendix 4

Aerial survey 2005 data for Akia-Manitsoq caribou population, Central region, West Greenland

Table 8. Raw data aerial survey Akia-Maniitsoq caribou herd, Central region, March 2005.

Date ddmmyy	Transect number	Density Stratum	Number Caribou observed on transect			Rear Seat Observers	
			Left front (CC)	Left rear	Right rear	Left	Right
14.03.05	77	High	10	0	0	JE	RH
14.03.05	97	High	10	13	2	JE	RH
14.03.05	17	High	17	6	0	JE	RH
14.03.05	39	High	8	11	40	JE	RH
14.03.05	84	High	6	7	7	JE	RH
14.03.05	199	High	13	14	9	JE	RH
14.03.05	164	High	5	4	1	JE	RH
14.03.05	181	High	0	0	0	JE	RH
14.03.05	58	High	0	0	0	JE	RH
14.03.05	56	High	0	0	33	JE	RH
14.03.05	107	High	5	5	0	JE	RH
14.03.05	200	High	6	15	0	RH	JE
14.03.05	183	High	1	1	0	RH	JE
14.03.05	3	High	0	0	0	RH	JE
14.03.05	87	High	7	7	1	RH	JE
14.03.05	124	High	5	5	0	RH	JE
14.03.05	227	High	11	11	5	RH	JE
14.03.05	68	High	4	4	4	RH	JE
15.03.05	18	High	9	10	11	RH	JE
15.03.05	1	High	23	16	22	RH	JE
15.03.05	21	High	0	0	3	RH	JE
15.03.05	8	High	13	11	0	RH	JE
15.03.05	193	High	9	11	10	RH	JE
15.03.05	36	High	27	27	4	RH	JE
15.03.05	191	High	36	28	4	RH	JE
15.03.05	108	High	10	10	0	RH	JE
15.03.05	96	High	5	0	9	RH	JE
15.03.05	64	High	7	7	1	JE	RH
15.03.05	136	High	0	0	7	JE	RH
15.03.05	166	High	2	2	10	JE	RH
15.03.05	203	High	0	0	2	JE	RH
15.03.05	197	High	0	0	0	JE	RH
15.03.05	135	High	1	1	0	JE	RH
15.03.05	141	High	0	0	0	JE	RH
15.03.05	19	High	4	4	0	JE	RH
15.03.05	201	High	0	0	0	JE	RH
15.03.05	46	High	3	5	0	JE	RH
15.03.05	65	High	12	12	9	JE	RH
15.03.05	186	High	0	0	0	JE	RH
16.03.05	95	Low	1	0	0	RH	JE
16.03.05	155	Low	5	4	1	RH	JE
16.03.05	121	Low	3	2	3	RH	JE
16.03.05	168	Low	4	4	0	RH	JE
16.03.05	28	Low	5	7	4	RH	JE
16.03.05	149	Low	0	0	11	RH	JE
16.03.05	61	Low	1	1	0	RH	JE
16.03.05	53	Low	0	0	0	RH	JE
16.03.05	15	Low	1	0	0	JE	RH

16.03.05	157	Low	8	8	0	JE	RH
16.03.05	92	Low	0	0	0	JE	RH
16.03.05	126	Low	5	5	1	JE	RH
16.03.05	105	Low	6	6	3	JE	RH
16.03.05	139	Low	4	4	0	JE	RH
16.03.05	52	Low	0	0	1	JE	RH
TOTAL			**554** (336 left side + 218 right side)				

Akia-Maniitsoq survey observers: (CC) Christine Cuyler, (JE) Johannes Egede, and (RH) Rink Heinrich.

*Table 9. **Random transects for aerial survey Akia-Maniitsoq caribou herd, Central region, March 2005.***

Date ddmmyy	Direction flown	Transect number	Transect start		Transect end	
			Latitude	Longitude	Latitude	Longitude
15.03.05	SW-NE	1	64º 47.14'	51º 32.91'	64º 50.49'	51º 27.56'
14.03.05	S-N	3	65º 05.79'	51º 22.96'	65º 09.80'	51º 21.80'
15.03.05	SE-NW	8	64º 49.86'	51º 03.41'	64º 53.51'	51º 07.52'
16.03.05	W-E	15	65º 20.68'	50º 47.81'	65º20.52'	50º38.12'
14.03.05	S-N	17	64º 36.97'	52º 04.81'	64º 40.68'	52º 01.00'
15.03.05	SE-NW	18	64º 43.05'	51º 20.32'	64º 45.39'	51º 28.05'
15.03.05	SSE-NNW	19	65º 05.24'	50º 31.98'	65º 09.15'	50º 34.45'
15.03.05	SE-NW	21	64º 46.09'	51º 02.62'	64º 49.33'	51º 08.32'
16.03.05	NW-SE	28	65º 31.96'	51º 04.32'	65º 30.11'	50º 55.63'
15.03.05	NW-SE	36	64º 56.09'	51º 20.72'	64º 54.46'	51º 11.98'
14.03.05	S-N	39	64º 40.85'	52º 03.31'	64º 43.95'	51º 57.21'
15.03.05	NW-SE	46	65º 02.89'	51º 12.83'	65º 00.80'	51º 04.61'
16.03.05	SSW-NNE	52	65º 40.79'	51º 56.24'	65º 44.54'	51º 52.55'
16.03.05	NW-SE	53	65º 27.61'	51º 42.92'	65º 25.81'	51º 34.19'
14.03.05	SSE-NNW	56	65º 18.61'	52º 01.44'	65º 22.37'	52º 05.01'
14.03.05	SSE-NNW	58	65º 19.84'	51º 44.91'	65º 23.29'	51º 49.99'
16.03.05	SW-NE	61	65º 23.39'	51º 21.39'	65º 26.66'	51º 15.66'
15.03.05	SW-NE	64	64º 49.53'	49º 53.16'	64º 50.56'	49º 43.96'
15.03.05	NW-SE	65	65º 05.11'	51º 06.50'	65º 01.78'	51º 01.07'
14.03.05	N-S	68	64º 25.95'	51º 40.69'	64º 22.11'	51º 37.73'
14.03.05	W-E	77	64º 18.11'	52º 06.29'	64º 18.99'	51º 57.18'
14.03.05	S-N	84	65º 00.67'	52º 10.06'	65º 04.40'	52º 06.31'
14.03.05	W-E	87	64º 58.78'	51º 34.97'	64º 58.55'	51º 25.42'
16.03.05	SW-NE	92	65º 21.48'	50º 30.04'	65º 24.06'	50º 22.56'
16.03.05	S-N	95	65º 36.87'	51º 40.90'	65º 40.92'	51º 41.22'
15.03.05	S-N	96	64º 46.69'	50º 30.23'	64º 50.72'	50º 31.05'
14.03.05	W-E	97	64º 28.06'	52º 06.60'	64º 29.03'	51º 57.48'
16.03.05	SSE-NNW	105	65º 38.69'	50º 27.48'	65º 42.25'	50º 32.19'
14.03.05	E-W	107	65º 22.37'	52º 15.41'	65º 21.66'	52º 24.97'
15.03.05	SW-NE	108	64º 51.34'	50º 38.18'	64º 54.72'	50º 32.96'
16.03.05	SW-NE	121	65º 36.60'	51º 22.38'	65º 38.27'	51º 13.44'
14.03.05	N-S	124	64º 53.44'	51º 36.66'	64º 49.51'	51º 38.92'
16.03.05	SW-NE	126	65º 36.02'	50º 47.44'	65º 37.47'	50º 38.29'
15.03.05	W-E	135	65º 03.43'	50º 14.72'	65º 03.25'	50º 05.14'
15.03.05	SE-NW	136	64º 49.88'	49º 57.96'	64º 53.40'	50º 02.64'
16.03.05	W-E	139	65º 31.92'	52º 02.11'	65º 32.39'	51º 52.4'
15.03.05	SW-NE	141	65º 07.52'	50º 28.98'	65º 11.23'	50º 25.13'
16.03.05	SW-NE	149	65º 29.47'	51º 09.85'	65º 30.74'	51º 00.58'
16.03.05	NW-SE	155	65º 37.49'	51º 35.26'	65º 35.85'	51º 26.31'
16.03.05	NW-SE	157	65º 21.24'	50º 37.14'	65º 18.50'	50º 30.00'

14.03.05	W-E	164	65º 05.81'	51º 53.45'	65º 05.72'	51º 43.85'
15.03.05	SSE-NNW	166	64º 53.92'	49º 59.59'	64º 57.85'	50º 01.89'
16.03.05	SW-NE	168	65º 31.49'	51º 16.54'	65º 33.14'	51º 07.62'
14.03.05	SE-NW	181	65º 06.81'	51º 42.78'	65º 10.39'	51º 47.28'
14.03.05	W-E	183	65º 03.25'	51º 25.54'	65º 01.64'	51º 16.74'
15.03.05	NW-SE	186	65º 10.27'	51º 04.97'	65º 07.62'	50º 57.69'
15.03.05	W-E	191	64º 50.56'	50º 54.21'	64º 49.24'	50º 45.21'
15.03.05	SE-NW	193	64º 52.77'	51º 13.97'	64º 54.99'	51º 21.95'
15.03.05	W-E	197	65º 02.10'	50º 19.68'	65º 01.59'	50º 10.18'
14.03.05	SW-NE	199	65º 08.02'	52º 02.68'	65º 10.53'	51º 55.12'
14.03.05	W-E	200	65º 02.04'	51º 44.44'	65º 03.51'	51º 35.50'
15.03.05	NE-SW	201	65º 09.10'	50º 38.21'	65º 07.59'	50º 47.14'
15.03.05	W-E	203	64º 58.96'	50º 27.64'	64º 59.29'	50º 18.10'
14.03.05	W-E	227	64º 38.00'	51º 33.97'	64º 37.95'	51º 24.53'

Table 10. Raw data aerial survey herd structure Akia-Maniitsoq caribou herd, Central region, March 2005.

Date ddmmyy	Transect number / Area Flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
14.03.05	17	5	5	0	0
14.03.05	17	9	8	0	1
14.03.05	39	4	3	1	0
14.03.05	39	4	0	2	2
14.03.05	39	1	0	0	1
14.03.05	39	3	0	0	3
14.03.05	39	5	3	1	1
14.03.05	39	11	7	2	2
14.03.05	39	8	5	2	1
14.03.05	39	16	16	0	0
14.03.05	164	3	0	3	0
14.03.05	164	2	0	2	0
14.03.05	56	5	0	5	0
14.03.05	56	17	8	4	5
14.03.05	200	2	0	1	1
14.03.05	200	2	0	1	1
14.03.05	87	2	2	0	0
14.03.05	124	2	2	0	0
14.03.05	124	2	0	1	1
14.03.05	Area 1	8	6	1	1
14.03.05	Area 1	4	2	2	0
14.03.05	Area 1	4	0	4	0
14.03.05	Area 1	6	2	4	0
14.03.05	Area 1	6	1	4	1
14.03.05	Area 1	5	5	0	0
14.03.05	Area 1	8	5	3	0
14.03.05	Area 1	2	0	2	0
15.03.05	Area 2 - W side Long Lake	6	0	5	1
15.03.05	Area 2 - W side Long Lake	6	0	4	2
15.03.05	Area 2 - Far W of Long Lake	9	0	7	2
15.03.05	Area 2 - W of S end Big Lake	4	1	2	1
15.03.05	Area 2 - W of S end Big Lake	5	0	4	1
15.03.05	Area 2 - W of S end Big Lake	2	0	1	1
15.03.05	Area 2 - W of S end Big Lake	2	0	1	1
15.03.05	Area 2 - W of S end Big Lake	3	2	1	0
15.03.05	Area 2 - W of S end Big Lake	3	0	3	0
15.03.05	Area 2 - W of S end Big Lake	3	1	1	1
15.03.05	1	2	0	1	1
15.03.05	1	2	0	1	1

15.03.05	1	5	0	5	0
15.03.05	1	3	1	1	1
15.03.05	1	3	0	3	0
15.03.05	1	8	3	5	0
15.03.05	1	6	0	5	1
15.03.05	1	3	3	0	0
15.03.05	1	2	0	2	0
15.03.05	1	5	0	4	1
15.03.05	1	2	0	1	1
15.03.05	1	2	0	1	1
15.03.05	1	4	0	4	0
15.03.05	1	12	2	10	0
15.03.05	Area 3 - Qugsuk Hi-Land	8	6	2	0
15.03.05	Area 3 - Qugsuk Hi-Land	10	0	9	1
15.03.05	Area 3 - Qugsuk Hi-Land	6	0	6	0
15.03.05	Area 3 - Qugsuk Hi-Land	4	0	4	0
15.03.05	Area 3 - Qugsuk Hi-Land	2	0	1	1
15.03.05	Area 3 - Qugsuk Hi-Land	7	0	7	0
15.03.05	Area 3 - Qugsuk Hi-Land	2	1	1	0
15.03.05	Area 3 - Qugsuk Hi-Land	9	1	8	0
15.03.05	Area 3 - Qugsuk Hi-Land	4	0	3	1
15.03.05	Area 3 - Qugsuk Hi-Land	5	0	4	1
15.03.05	Area 4 - near 36	7	0	7	0
15.03.05	Area 4 - near 36	2	0	1	1
15.03.05	Area 4 - S mouth of Eldorado Valley	7	1	5	1
15.03.05	Area 4 - S mouth of Eldorado Valley	6	2	4	0
15.03.05	Area 4 - S mouth of Eldorado Valley	1	0	1	0
15.03.05	Area 4 - S mouth of Eldorado Valley	3	1	1	1
15.03.05	Area 4 - S mouth of Eldorado Valley	8	1	4	3
15.03.05	Area 4 - S mouth of Eldorado Valley	2	0	1	1
15.03.05	Area 4 - S mouth of Eldorado Valley	1	0	1	0
15.03.05	Area 4 - S mouth of Eldorado Valley	3	3	0	0
15.03.05	Area 4 - S mouth of Eldorado Valley	2	0	2	0
15.03.05	Area 4 - S mouth of Eldorado Valley	1	0	1	0
15.03.05	Area 4 - S mouth of Eldorado Valley	6	1	3	2
15.03.05	Area 4 - S mouth of Eldorado Valley	3	0	3	0
15.03.05	Area 4 - S mouth of Eldorado Valley	5	1	3	1
15.03.05	Area 4 - S mouth of Eldorado Valley	4	2	2	0
15.03.05	Area 4 - S mouth of Eldorado Valley	4	0	2	2
15.03.05	Area 4 - S mouth of Eldorado Valley	5	1	3	1
15.03.05	Area 4 - S mouth of Eldorado Valley	3	0	3	0
15.03.05	Area 4 - S mouth of Eldorado Valley	3	0	3	0
15.03.05	Area 5 - Small Valley N of muskox pt	11	0	7	4
15.03.05	Area 5 - Small Valley N of muskox pt	2	0	1	1
15.03.05	Area 5 - Small Valley N of muskox pt	2	0	2	0
15.03.05	Area 5 - Small Valley N of muskox pt	1	0	1	0
15.03.05	Area 5 - Small Valley N of muskox pt	7	0	5	2
15.03.05	Area 5 - Small Valley N of muskox pt	5	1	3	1
15.03.05	Area 5 - Small Valley N of muskox pt	6	0	5	1
15.03.05	Area 5 - Small Valley N of muskox pt	9	2	5	2
15.03.05	136	2	0	2	0
15.03.05	Area 4 – near 46	1	1	0	0
15.03.05	Area 4 – near 46	2	0	1	1
15.03.05	Area 4 – near 65	2	0	2	0
16.03.05	Area 6 - between 61-15	2	0	1	1
16.03.05	Area 6 - between 61-15	4	0	4	0
16.03.05	Area 6 - between 61-15	3	2	1	0
16.03.05	Area 6 - between 61-15	4	2	0	2
16.03.05	Area 6 - between 61-15	4	0	0	4
16.03.05	Area 6 - between 61-15	4	0	1	3

16.03.05	Area 6 - between 61-15	3	0	0	3
16.03.05	Area 6 - between 61-15	3	1	1	1
16.03.05	Area 6 - between 61-15	2	1	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	1	1
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	1	1
16.03.05	Area 4 - Highway valley NE of Eldorado	1	0	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	3	0
16.03.05	Area 4 - Highway valley NE of Eldorado	5	1	3	1
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	1	2
16.03.05	Area 4 - Highway valley NE of Eldorado	1	0	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	4	0	4	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	2	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	2	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	2	0
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	3	0
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	3	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	2	0	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	2	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	1	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	1	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	6	0	5	1
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	3	0
16.03.05	Area 4 - Highway valley NE of Eldorado	7	0	7	0
16.03.05	Area 4 - Highway valley NE of Eldorado	6	2	4	0
16.03.05	Area 4 - Highway valley NE of Eldorado	1	0	1	0
16.03.05	Area 4 - Highway valley NE of Eldorado	3	0	3	0
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	1	1
16.03.05	Area 4 - Highway valley NE of Eldorado	2	0	0	2
16.03.05	Area 4 - Eldorado N to middle	2	0	1	1
16.03.05	Area 4 - Eldorado N to middle	1	1	0	0
16.03.05	Area 4 - Eldorado N to middle	8	8	0	0
16.03.05	Area 4 - Eldorado N to middle	4	0	4	0
16.03.05	Area 4 - Eldorado N to middle	3	0	3	0
16.03.05	Area 4 - Eldorado N to middle	2	0	1	1
16.03.05	Area 4 - Eldorado N to middle	4	1	1	2
16.03.05	Area 4 - Eldorado N to middle	5	0	5	0
16.03.05	Area 4 - Eldorado N to middle	6	1	5	0
16.03.05	Area 4 - Eldorado N to middle	5	0	5	0
16.03.05	Area 4 - Eldorado N to middle	7	1	6	0
16.03.05	Area 4 - Eldorado N to middle	7	3	3	1
16.03.05	Area 4 - Eldorado N to middle	5	0	4	1
16.03.05	Area 4 - Eldorado N to middle	3	0	3	0
16.03.05	Area 4 - Eldorado N to middle	7	1	5	1
16.03.05	Area 4 - Eldorado N to middle	14	4	8	2
16.03.05	Area 4 - Eldorado N to middle	3	1	2	0
16.03.05	Area 4 - Eldorado N to middle	4	0	4	0
16.03.05	Area 4 - Eldorado N to middle	4	1	3	0
16.03.05	Area 4 - Eldorado N to middle	5	0	5	0
16.03.05	Area 4 - Eldorado N to middle	2	0	2	0
16.03.05	Area 4 - Eldorado N to middle	3	2	1	0
16.03.05	Area 4 - Eldorado N to middle	2	0	2	0
16.03.05	Area 4 - Eldorado N to middle	2	0	2	0
16.03.05	Area 4 - Eldorado N to middle	3	0	3	0
16.03.05	Area 4 - Eldorado N to middle	6	2	4	0
16.03.05	Area 4 - Eldorado N to middle	6	2	4	0
16.03.05	Area 4 - Eldorado N to middle	3	0	3	0
16.03.05	Area 4 - Eldorado N to middle	8	5	3	0
16.03.05	Area 4 - Eldorado N to middle	9	4	5	0
16.03.05	Area 4 - Eldorado N to middle	3	1	2	0
16.03.05	Area 4 - Eldorado N to middle	3	0	3	0

16.03.05	Area 4 - Eldorado N to middle	4	4	0	0
16.03.05	Area 4 - Eldorado N to middle	2	2	0	0
16.03.05	Area 4 - Eldorado N to middle	6	1	5	0
16.03.05	Area 4 - Eldorado N to middle	13	11	2	0
	TOTALS	**705**	**187**	**419**	**99**

Appendix 5

Aerial survey 2005 data for Kangerlussuaq-Sisimiut caribou population, North region, West Greenland

Table 11. Raw data aerial survey Kangerlussuaq-Sisimiut caribou herd, North region, March 2005.

Date ddmmyy	Transect number	Density Stratum	Number Caribou observed on transect			Rear Seat Observers	
			Left front (CC)	Left rear	Right rear	Left	Right
18.03.05	77	Low	6	6	6	HM	RH
18.03.05	64	Low	6	8	2	HM	RH
18.03.05	27	Low	0	1	0	HM	RH
18.03.05	151	Low	1	0	0	HM	RH
18.03.05	161	Low	10	7	2	HM	RH
18.03.05	113	Low	1	1	0	HM	RH
18.03.05	101	Low	12	14	0	HM	RH
18.03.05	47	Low	0	0	1	RH	HM
18.03.05	155	Low	0	0	26	RH	HM
18.03.05	87	Low	0	0	0	RH	HM
18.03.05	29	Low	3	3	0	RH	HM
18.03.05	120	High	22	23	19	RH	HM
18.03.05	193	High	6	7	9	RH	HM
18.03.05	203	High	37	24	37	RH	HM
18.03.05	143	Low	0	0	7	RH	HM
18.03.05	139	High	13	13	13	RH	HM
18.03.05	122	High	4	3	4	RH	HM
18.03.05	202	High	3	3	13	RH	HM
18.03.05	115	High	12	12	8	RH	HM
18.03.05	76	High	9	12	9	RH	HM
18.03.05	172	High	36	36	11	RH	HM
18.03.05	211	High	6	6	2	RH	HM
18.03.05	200	High	13	18	18	RH	HM
19.03.05	125	Low	0	0	0	HM	RH
19.03.05	32	Low	2	2	6	HM	RH
19.03.05	8	Low	28	37	15	HM	RH
19.03.05	61	Low	0	1	0	HM	RH
19.03.05	135	Low	1	1	4	HM	RH
19.03.05	5	Low	14	13	18	HM	RH
19.03.05	150	Low	0	1	6	HM	RH
19.03.05	158	Low	0	1	0	HM	RH
19.03.05	175	High	3	3	4	RH	HM
19.03.05	24	High	15	15	10	RH	HM
19.03.05	10	High	17	20	23	RH	HM
19.03.05	34	High	15	15	19	RH	HM
19.03.05	183	High	4	4	3	RH	HM
19.03.05	137	High	8	13	39	RH	HM
19.03.05	36	High	15	14	9	RH	HM
19.03.05	116	High	59	57	23	RH	HM
19.03.05	152	High	5	5	13	RH	HM
21.03.05	73	High	17	16	7	HM	RH
21.03.05	9	High	7	20	22	HM	RH
21.03.05	153	High	0	2	6	HM	RH
21.03.05	142	High	11	11	12	HM	RH
21.03.05	192	High	15	32	12	HM	RH
21.03.05	106	High	15	30	14	HM	RH
21.03.05	58	High	10	11	7	HM	RH
21.03.05	149	High	0	9	9	HM	RH

21.03.05	197	High	13	7	11	HM	RH
21.03.05	189	High	8	17	0	HM	RH
22.03.05	59	High	6	4	6	RH	HM
22.03.05	70	High	11	11	17	RH	HM
22.03.05	63	High	8	2	6	RH	HM
22.03.05	154	High	8	10	23	RH	HM
22.03.05	104	High	6	6	8	RH	HM
22.03.05	210	High	10	7	7	RH	HM
22.03.05	209	High	4	4	3	RH	HM
22.03.05	65	High	10	10	24	RH	HM
22.03.05	112	High	24	22	5	HM	RH
22.03.05	92	High	19	17	15	HM	RH
TOTAL			**1284** (691 left side + 593 right side)				

Kangerlussuaq-Sisimiut observers: (CC) Christine Cuyler, (RH) Rink Heinrich , and(HM) Hans Mølgaard.

Table 12. Random transects for aerial survey Kangerlussuaq-Sisimiut caribou herd, North region, March 2005.

Date ddmmyy	Direction flown	Transect number	Transect start DD mm.m		Transect end DD mm.m	
			Latitude	Longitude	Latitude	Longitude
19.03.05	NE-SW	5	66º 30.3'	50º 24.5'	66º 28.9'	50º 34.0'
19.03.05	SE-NW	8	66º 44.4'	50º 20.4'	66º 46.5'	50º 29.2'
21.03.05	SW-NE	9	67º 13.0'	50º 20.4'	67º 16.4'	50º 14.4'
19.03.05	SE-NW	10	66º 59.1'	51º 12.8'	67º 01.9'	51º 20.3'
19.03.05	WSW-ENE	24	66º 56.9'	51º 19.6'	66º 55.0'	51º 28.7'
18.03.05	NE-SW	27	66º 35.0'	52º 14.4'	66º 33.1'	52º 23.3'
18.03.05	WSW-ENE	29	67º 26.8'	52º 59.0'	67º 28.5'	52º 49.3'
19.03.05	SE-NW	32	66º 51.7'	49º 56.0'	66º 55.1'	50º 01.7'
19.03.05	SW-NE	34	67º 02.3'	51º 17.5'	67º 06.2'	51º 14.3'
19.03.05	S-N	36	67º 14.2'	51º 05.3'	67º 10.5'	51º 01.3'
18.03.05	ESE-WNW	47	67º 01.5'	53º 31.1'	67º 02.4'	53º 41.2'
21.03.05	W-E	58	67º 15.3'	50º 51.3'	67º 16.9'	50º 41.8'
22.03.05	SW-NE	59	67º 17.2'	49º 59.5'	67º 20.5'	49º 53.3'
19.03.05	SE-NW	61	66º 39.4'	50º 37.2'	66º 42.1'	50º 44.8'
22.03.05	SE-NW	63	67º 39.3'	50º 11.7'	67º 41.5'	50º 20.7'
18.03.05	NW-SE	64	66º 36.6'	51º 53.9'	66º 36.6'	51º 43.7'
22.03.05	NE-SW	65	67º 33.1'	51º 36.5'	67º 36.5'	51º 30.4'
22.03.05	SE-NW	70	67º 21.9'	50º 09.6'	67º 24.9'	50º 16.6'
21.03.05	WNW-ESE	73	67º 09.9'	50º 25.6'	67º 09.2'	50º 15.4'
18.03.05	W-E	76 *	67º 30.7'	51º 52.5'	67º 34.1'	51º 47.2'
18.03.05	SW-NE	77	66º 47.1'	51º 52.8'	66º 43.7'	51º 58.3'
18.03.05	S-N	87	67º 18.8'	53º 01.6'	67º 22.6'	53º 05.2'
22.03.05	NE-SW	92	67º 29.2'	51º 14.7'	67º 26.8'	51º 23.2'
18.03.05	SSE-NNW	101	66º 21.0'	53º 26.8'	66º 24.6'	53º 31.4'
22.03.05	SE-NW	104	67º 40.9'	50º 45.4'	67º 42.6'	50º 55.0'
21.03.05	NE-SW	106	67º 22.4'	50º 42.1'	67º 18.6'	50º 46.3'
22.03.05	S-N	112	67º 27.4'	51º 06.0'	67º 31.4'	51º 08.2'
18.03.05	SE-NW	113	66º 33.7'	53º 08.1'	66º 36.6'	53º 15.1'
18.03.05	NW-SE	115	67º 35.1'	51º 47.6'	67º 38.0'	51º 55.0'
19.03.05	SW-NE	116	67º 04.4'	50º 44.9'	67º 08.2'	50º 41.7'
18.03.05	SSE-NNW	120	67º 27.1'	52º 33.1'	67º 30.9'	52º 36.6'
18.03.05	SSE-NNW	122	67º 26.2'	52º 09.4'	67º 22.8'	52º 03.8'
19.03.05	E-W	125	66º 56.3'	50º 35.8'	66º 55.9'	50º 25.5'
19.03.05	S-N	135	66º 34.5'	50º 32.9'	66º 38.5'	50º 34.3'
19.03.05	SW-NE	137	67º 13.2'	51º 15.0'	67º 17.1'	51º 12.5'
18.03.05	SSE-NNW	139	67º 23.2'	52º 20.7'	67º 19.9'	52º 14.9'
21.03.05	NW-SE	142	67º 18.6'	50º 10.2'	67º 21.5'	50º 17.4'
21.03.05	SSE-NNW	143	67º 20.4'	52º 38.9'	67º 17.0'	52º 33.2'
21.03.05	E-W	149	67º 17.7'	51º 02.7'	67º 17.7'	50º 52.2'
19.03.05	E-W	150	66º 30.9'	50º 49.8'	66º 31.0'	50º 59.9'
18.03.05	SSW-NNE	151	66º 38.6'	52º 34.9'	66º 42.5'	52º 31.9'

19.03.05	WSW-ENE	152 **	67º 04.3'	50º 41.5'	67º 06.2'	50º 32.3'
21.03.05	SW-NE	153	67º 13.2'	50º 33.2'	67º 16.8'	50º 28.2'
22.03.05	S-N	154	67º 41.9'	50º 32.8'	67º 45.8'	50º 35.2'
18.03.05	WSW-ENE	155	67º 22.9'	53º 37.2'	67º 24.8'	53º 27.9'
19.03.05	SW-NE	158	66º 34.4'	51º 26.5'	66º 37.8'	51º 21.0'
18.03.05	SSW-NNE	161	66º 36.5'	52º 56.1'	66º 40.3'	52º 52.3'
18.03.05	NW-SE	172	67º 30.5'	51º 43.6'	67º 28.7'	51º 34.1'
19.03.05	WSW-ENE	175	66º 48.3'	51º 44.0'	66º 49.6'	51º 34.3'
19.03.05	W-E	183 ***	67º 01.1'	51º 08.6'	67º 02.2'	50º 58.6'
21.03.05	NW-SE	189	67º 25.4'	50º 49.5'	67º 27.2'	50º 58.9'
21.03.05	SE-NW	192	67º 21.4'	50º 30.8'	67º 25.5'	50º 34.3'
18.03.05	SW-NE	193	67º 32.3'	52º 27.0'	67º 34.7'	52º 18.5'
21.03.05	SE-NW	197	67º 21.8'	50º 51.6'	67º 24.3'	50º 59.8'
18.03.05	NW-SE	200	67º 04.9'	51º 22.7'	67º 06.4'	51º 32.4'
18.03.05	SE-NW	202	67º 35.5'	52º 00.8'	67º 32.4'	51º 54.0'
18.03.05	SW-NE	203	67º 31.2'	52º 22.1'	67º 27.3'	52º 24.4'
22.03.05	SW-NE	209	67º 34.6'	51º 22.8'	67º 37.9'	51º 16.4'
22.03.05	NNE-SSW	210	67º 34.3'	51º 11.7'	67º 38.3'	51º 10.7'
18.03.05	NW-SE	211	67º 11.6'	51º 30.9'	67º 14.2'	51º 38.9'

* Transect 76 – the original 2000 end point, 67º 32.4'N / 51º 49.9'W made transect too short therefore corrected in 2005.
** Transect 152 – Pilot error in 2005 on key-in of transect end points, caused this end point to actually be 66º 37.1'N; 50º 33.5'W.
*** Transect 183 – Typo error in data sheet from 2000 made transect too short. Was 50º 08.6' in table, here corrected to 51º 08.6'.

Table 13. *Raw data aerial survey herd structure Kangerlussuaq-Sisimiut caribou herd, North region, March 2005.*

Date ddmmyy	Transect number / Area Flown	Group Size	Males (Age > 1 year)	Females (Age > 1 year)	Calves (Age < 1 year)
18.03.05	29	3	0	3	0
18.03.05	203	2	0	1	1
18.03.05	203	2	0	1	1
18.03.05	203	3	1	2	0
18.03.05	203	6	2	2	2
18.03.05	203	2	0	1	1
18.03.05	203	6	3	3	0
18.03.05	143	2	0	0	2
18.03.05	139	2	0	1	1
18.03.05	122	1	0	0	1
18.03.05	122	3	0	0	3
18.03.05	203	5	5	0	0
18.03.05	203	3	3	0	0
18.03.05	203	2	0	1	1
18.03.05	203	4	1	2	1
18.03.05	203	4	1	3	0
18.03.05	203	2	2	0	0
18.03.05	203	8	4	4	0
18.03.05	203	3	0	1	2
18.03.05	203	6	0	3	3
18.03.05	203	4	1	3	0
18.03.05	203	13	1	8	4
18.03.05	203	12	2	8	2
18.03.05	203	4	0	2	2
18.03.05	203	5	0	5	0
18.03.05	203	6	0	4	2
18.03.05	202	2	0	2	0
18.03.05	172	1	1	0	0

18.03.05	172	2	0	1	1
18.03.05	172	3	0	3	0
18.03.05	172	9	1	7	1
18.03.05	172	2	0	2	0
18.03.05	172	6	0	6	0
18.03.05	172	17	6	10	1
18.03.05	172	3	0	2	1
18.03.05	211	2	0	2	0
18.03.05	200	2	0	2	0
18.03.05	200	4	0	2	2
19.03.05	32	1	1	0	0
19.03.05	32	1	1	0	0
19.03.05	8	3	0	3	0
19.03.05	8	2	0	2	0
19.03.05	8	2	0	2	0
19.03.05	8	4	2	2	0
19.03.05	8	1	0	1	0
19.03.05	8	2	0	2	0
19.03.05	8	1	1	0	0
19.03.05	8	8	2	6	0
19.03.05	8	8	1	7	0
19.03.05	8	3	0	3	0
19.03.05	8	3	0	3	0
19.03.05	8	4	0	4	0
19.03.05	24	2	0	1	1
19.03.05	24	2	2	0	0
19.03.05	24	4	0	2	2
19.03.05	34	4	1	3	0
19.03.05	34	4	0	3	1
19.03.05	34	5	1	4	0
19.03.05	34	2	0	1	1
19.03.05	34	4	2	1	1
19.03.05	137	17	3	11	3
19.03.05	137	11	6	5	0
19.03.05	137	5	3	2	0
19.03.05	137	7	3	4	0
19.03.05	137	2	0	1	1
19.03.05	137	7	6	1	0
19.03.05	137	5	2	1	2
19.03.05	137	5	3	2	0
19.03.05	137	4	2	2	0
19.03.05	137	4	1	3	0
19.03.05	137	1	0	1	0
19.03.05	137	2	0	2	0
19.03.05	137	4	1	3	0
19.03.05	137	11	2	7	2
19.03.05	137	4	2	2	0
19.03.05	36	2	0	2	0
19.03.05	36	3	1	2	0
19.03.05	116	3	0	1	2
19.03.05	116	5	0	5	0
19.03.05	116	8	1	7	0
19.03.05	116	9	0	9	0
19.03.05	116	14	1	13	0

19.03.05	116	14	0	14	0
19.03.05	116	7	0	7	0
19.03.05	116	4	1	3	0
19.03.05	116	4	0	4	0
19.03.05	116	9	3	6	0
21.03.05	73	3	0	3	0
21.03.05	73	5	1	4	0
21.03.05	9	4	1	3	0
21.03.05	192	6	0	5	1
21.03.05	106	6	0	6	0
21.03.05	58	1	1	0	0
21.03.05	197	3	0	3	0
21.03.05	197	2	1	1	0
21.03.05	189	1	0	0	1
21.03.05	153	8	1	7	0
21.03.05	115	4	1	3	0
21.03.05	115	6	0	6	0
21.03.05	115	16	0	16	0
21.03.05	115	3	0	3	0
21.03.05	115	3	0	3	0
21.03.05	115	12	2	10	0
21.03.05	115	4	0	4	0
21.03.05	115	2	0	1	1
21.03.05	115	13	2	11	0
21.03.05	115	13	3	10	0
21.03.05	115	5	2	1	2
22.03.05	59	3	0	3	0
22.03.05	70	4	0	4	0
22.03.05	70	3	0	3	0
22.03.05	154	4	0	4	0
22.03.05	154	2	0	1	1
22.03.05	154	1	0	0	1
22.03.05	154	2	0	2	0
22.03.05	104	2	0	0	2
22.03.05	210	5	5	0	0
22.03.05	209	2	2	0	0
22.03.05	209	2	0	2	0
22.03.05	209	3	1	2	0
22.03.05	65	6	0	4	2
22.03.05	112	5	0	5	0
22.03.05	112	2	2	0	0
22.03.05	92	5	0	4	1
22.03.05	92	16	1	15	0
22.03.05	92	4	0	4	0
22.03.05	92	3	0	0	3
22.03.05	92	5	0	5	0
22.03.05	92	2	0	2	0
22.03.05	92	2	0	2	0
22.03.05	92	7	0	7	0
22.03.05	92	3	0	3	0
22.03.05	92	2	0	0	2
22.03.05	112	6	1	5	0
22.03.05	112	5	1	4	0
22.03.05	112	5	5	0	0

22.03.05	112	5	1	4	0
22.03.05	112	7	1	6	0
22.03.05	112	2	0	1	1
22.03.05	112	5	0	4	1
22.03.05	112	2	0	2	0
22.03.05	112	7	1	4	2
22.03.05	112	6	0	6	0
22.03.05	112	8	4	4	0
22.03.05	112	6	0	5	1
22.03.05	112	3	1	2	0
22.03.05	112	6	2	4	0
22.03.05	112	2	2	0	0
22.03.05	Between transects 92 and 137+197	7	2	5	0
22.03.05	Between transects 92 and 137+197	4	4	0	0
22.03.05	S of Isortoq River; WNW of line 116	2	0	1	1
22.03.05	S of Isortoq River; WNW of line 116	5	2	3	0
22.03.05	S of Isortoq River; WNW of line 116	3	2	1	0
22.03.05	W20 (Grid Cell)	7	0	1	6
22.03.05	W20 (Grid Cell)	2	2	0	0
22.03.05	S19 (Grid Cell)	4	3	0	1
22.03.05	P21 (Grid Cell)	1	1	0	0
22.03.05	P21 (Grid Cell)	2	2	0	0
22.03.05	P21 (Grid Cell)	3	3	0	0
22.03.05	P21 (Grid Cell)	2	2	0	0
22.03.05	K20 (Grid Cell)	6	6	0	0
TOTALS		**745**	**163**	**501**	**81**

Appendix 6

Recommendations for future

Aerial survey methods & design

To ensure that caribou can be spotted, the methods described in this report should be used in future aerial surveys. Further, if financially possible more transects are recommended in the low-density strata, as these would reduce variance.

Sighting caribou

Although seldom significant ($P < 0.05$), fewer caribou were always observed on the right side of the helicopter, where only one observer was present relative to the left side of the helicopter, where two observers independently counted animals (Table 14). We suggest that a subconscience element of competition existed between the two left side observers, since their results will be compared against each other. This sharpened their concentration and more caribou present on the transect were spotted. Competition, real or imaginary, may be a method to further reduce the number of missed caribou on a survey.

Table 14. *Summary of caribou observed on the left and right side of the helicopter.*

Caribou population surveyed	Number caribou observed Left Side	Number caribou observed Right Side	Significance[4] $P(T \leq t)$ 2-tail
March 2000 Survey[1&2]			
Kangerlussuaq-Sisimiut	619	386	**P = 0.001**
Neria	201	131	**P = 0.083**
March 2001 Survey[3]			
Akia-Maniitsoq	335	296	**P = 0.576**
Ameralik	343	289	**P = 0.417**
Qeqertarsuatsiaat	68	28	**P = 0.103**
March 2005 Survey[4]			
Akia-Maniitsoq	336	218	**P = 0.101**
Kangerlussuaq-Sisimiut	691	593	**P = 0.223**
TOTAL	**2593**	**1941**	**P = 0.011**

[1] Cuyler et al 2002; [2] Cuyler et al 2004; [3] Cuyler et al 2003; [4] t-Test paired two sample for means.

Since we were interested in which observer saw more caribou and not how much more they saw, binomial non-parametric tests were used to test for this possible “competition” effect between observers. We tested the accumulative sum of caribou sighted on the left and right side of the helicopter using all data from the 2001 and 2005 surveys. First we tested the two observers on the left side against each other, secondly the left and right rear seat observers were compared. Between left side observers the difference in spotted caribou was not significant (P = 0.84). However, the difference between left and right rear seat observers was significant (P = 0.02). This result supports our hypothesis that more caribou are spotted when two observers simultaneaously, yet independently, scan the transect strip for animals.

Therefore we recommend two observers on both sides of the helicopter for future surveys. This is difficult but not impossible with the AS350 helicopter. The second observer for the right rear side could take the middle seat between transects and move to a cramped crouch for actual transects. Flying time on a transect is six to nine minutes, which is not too long a period to maintain an awkward position. If observers took turns being second observer on the right rear side, than no one person suffered for long periods. Alternatively a larger helicopter with room for three observers left side and two on the right might be used. Given that a correction factor is already applied to the results obtained by three observers, it may be argued that a fourth observer or bigger helicopter may not the improve the accuracy of the final estimate enough to justify the increased expense.

Logistics Tips

Refueling is not always possible between 09:00 and 17:00, Monday to Friday, specifically at Sisimiut airport, which can close early, e.g. 14:00, and possibly also at Maniitsoq. Telephone on the specific day to obtain update on whether refueling is possible and when.

Refueling in Kapisillit or Qeqertarsuatsiaat (Fiskenæsset) is only possible if fuel barrels are already there, and pilot has pumping gear onboard. Refueling may take up to two hours if conditions are adverse.

All airports are closed for Sundays and holidays, unless your project is willing to pay to keep them open.

Helicopter pilots are prohibited from flying more than 7 hours per day. Safety considerations would suggest that less than 7 hours is better when flying the low slow transects used in the caribou surveys.

Bring totally non-scratch cloths, which are approved by AirGreenland Helicopter Charter department to wipe condensation off the inside of the helicopter’s front window.

Book the time period for helicopter use well in advance (minimum two months) and check as to whether AirGreenland has other plans for their helicopter or pilot during

the time period for the intended survey. One year, AirGreenland neglected to inform us that their pilot was obliged to participate in an AirGreenland pilots training course. This interrupted the survey when weather was optimal.
Make sure the helicopter has a SATELLITE TELEPHONE. For safety reasons helicopter pilots must call-in by radio to AirGreenland every half-hour and give their position. Since radio contact is impossible at the 15 m flight altitudes used during the survey. The pilot must drop what he's doing and gain altitude until contact is made. This causes delays and can result in wasted time, i.e. extra expense, for the surveys. With a satellite telephone the pilot can make contact with AirGreenland regardless of where we are in the terrain.
Start and end GPS points keyed-in by the pilot should always be checked prior to takeoff.
Check from helicopter GPS that all transects entered have length 7.5 km.
Check that all transects are actually in helicopter GPS. The number of data points may exceed memory of helicopter GPS, which caused all the first transects entered to be erased in 2005.
Check pilot's print-out of transect points with your own, and pick out discrepancies prior to take-off.
Always carry your original print-out of transect start and end points with you in helicopter for consultation in case the above still does not catch all human errors.

Appendix 7

List of terms

Accuracy –how well a survey estimate for animal numbers reflects the true population size.

Annual – occurring, or done every year.

Bias – describes how far the average value of the estimator is from the true population value. An unbiased estimator centres about the true value for the population. Bias is the extent to which an estimate is systematically wrong. Bias decreases the accuracy of a survey. In popular terms, negative bias in surveys moves the final estimate to below the true population size and positive bias can move it above the true population size.

Body condition – pertaining to amount of fat present, i.e. plenty of fat equals excellent body condition.

Bootstrapping – statistical tool to arrive at confidence intervals without knowledge of the distribution of the parameter in question.

Confidence interval – statistical term for when the standard error (SE) is combined with a probability (*P*) level to yield confidence limits (CL) and their interval, the confidence interval (CI). For example: at a $P = 0.90$ ($\alpha = 0.1$) then assuming no bias a 90% CI is likely to contain the true population size in 90% of surveys of the same type and intensity. NOTE: it is incorrect to state that there is a 90% chance that the actual number of caribou in a survey area is within the CI.

Criteria – standards set on which judgement can be made, i.e. the sex or age of a caribou.

Density – the number of caribou per square kilometre of land area.

Estimate – a calculation as to the likely or approximate size of the caribou population.

Fecundity – related to fertility and is the potential level of reproductive performance of a population, which is usually much greater than the realised reproduction (fertility). However, fecundity and fertility are often used inconsistently and even interchangeably in the literature.

Fertility – of a population is the number of live births over a time period, usually a year, e.g. the number of live births per female, or the number of female young born per female. To calculate fertility we need to know the average litter size, average number of litters produced per time interval (year) and the sex ratio at birth (Caughley 1977).

Fertility index – see also under *recruitment*. Ratio of calves to females or calves to adults.

Herd – see also under *population*. Greenlandic caribou seldom or never aggregate into large coherent groups. Group size typically stays under 4 animals, with groups scattered throughout a large area.

Herd structure – this is the sex and age distribution of the animals within a given population/herd.

Logistics – the obtaining, distribution, maintenance and replacement of field equipment and personnel.

Management – e.g. wildlife management, which is the act of manipulating, directing, controlling, regulating and/or administrating a wildlife resource and any number of the factors affecting that wildlife resource.

Natural mortality – all mortality due to factors other than hunting (disease, accident, starvation, predation, parasites, etc.).

Net recruitment – or rate of increase of the herd is determined by subtracting the adult mortality rate from the gross recruitment.

Population – see also under *herd*. All the animals of the same species living in a specific region, which do not mix with animals of the same species from other regions, i.e. they are reproductively isolated. A population is a demographic unit distinct by virtue of its unique density, distribution, birth & death rate, sex & age structure, immigration & emigration rates, and other demographic parameters.

Population status – states a wildlife species' occurrence and abundance, i.e. where and how many.

Population analysis – attempts to determine herd structure (sex & age) and the forces controlling the composition of the population/herd.

Population dynamics – in any analysis of herd structure and status the parameters are seldom if ever static, therefore the term population *dynamics*.

Precision – is a measure of the quality of the survey estimate for animal number, i.e. how close you could expect the estimate to approximate its expected value. Precision refers to the variation in repeated measurement of the same quantity. Precision is determined primarily by the variation in the population and the size of the sample. An indicator of the precision of an estimate is the confidence interval.

Range – the extent of the land area on which the caribou wander and graze. The land area used during foraging/calving/rutting by the caribou, e.g. summer and winter ranges. The word is often synonymous with pasture or habitat, however, the term range brings vegetation to mind rather than for example topography.

Recruitment – see also under *fertility index*. The late winter (March) value for calves/100 cows, which indicates the increment in caribou number for a specific population/herd from one year to the next.

Sightability – the probability of actually seeing a caribou present within the strip flown.

Standard error (SE) – standard error is the standard deviation (SD) divided by the square root of sample size (n) or (n-1) if SD is calculated using n and not n-1. Sampling error would be zero if the same number of caribou were seen on each transect flown.

Strata – (plural of stratum) in this report refers to the division of the North region according to caribou density present.

Terrain – refers to the land or ground, usually in conjunction with a description of topography, e.g. rough terrain, mountainous terrain, etc.

Variance – statistical term for the amount of variation in measurements. Variance is the expected square deviance regardless of the distribution. Its square root is standard deviation (SD). Note: variance is distribution independent. It is simply the expected square deviation.

Appendix 8

Comments from local observers

Hans Mølgaard – SISIMIUT 23 March 2005

(Literal translation to English from Danish)

Piniarnermik Aalisarnermillu Nakkutilliisut

Hunting and Fishing Officer

Sisimiut

Sisimiut 23 March 2005

Christine Cuyler
Pinngortitaleriffik, Greenland Institute of Natural Resources
Box 570, 3900 NUUK

RE: Short description of the caribou survey 2005 in the Sisimiut hinterland and Kangerlussuaq south area.

Between 1992 and 1996 I participated in surveys for both muskoxen and caribou, where we flew with a fixed-wing airplane. During these flights, we flew at an altitude of 150 metres, but at times we flew from mountain top to mountain top without changing altitude despite that between these mountaintops there could be deep valleys, where the height difference could be 500 metres. Fixed wing aircraft fly and therefore their speed is always rather fast, and the transects were long, sometimes extending from Kangerlussuaq right up to Nordre Strømfjord. As well, the flights could last eight hours at a time, "yes that was eight hours in the air". So that it was a sure thing that one was tired and exhausted after flying eight hours.
But the aerial survey of 2005 by helicopter was something completely different. It was flown at an altitude of about 15 metres, at a speed of about 55 kilometres per hour and we could follow the undulations of the terrain exactly, and here the pilot must be praised for his exceedingly excellent flying. Transects were 7.5 kilometres in length. In contrast between 1992 and 1996 the transects could be 130 kilometres in length, and therefore this year's survey, seen from my perspective, is the best counting method done to date. We could count the exact number of animals we saw, 300 metres to the side from the helicopter, and the entire time we could note caribou, ptarmigan, arctic hares and blue or white foxes.
And one thing is certain, today caribou and muskoxen live side by side, so the myth, i.e. these two species cannot tolerate each other, is totally out-in-the-weather [read: out-to-lunch], but perhaps the myth applied at the dawn of time, but not today. Today these two species have simply learned to know each other.

Yours truly,
Hans Mølgaard
Hunting and Fishing Officer
Sisimiut

Aalisarnermik Piniarnermillu Nakkutilliisoq
Hunting and Fishing Officer
Tel: 866338, Cellphone: 528554, fax: 866339
E-mail: jagtfisk@greennet.gl

Hans Mølgaard – SISIMIUT 23/03-2005 (in Danish)

Piniarnermik Aalisarnermillu Nakkutilliisut

Jagt og Fiskeribetjent

Sisimiut

Sisimiut den 23.marts 2005

Christine Cuyler
Pinngortitaleriffik Grønlands Naturinstitut
Box 570, 3900 NUUK

Vedr.: kort beskrivelse om Rensdyrtælling 2005 i Sisimiut bagland og Kangerlussuaq syd.

Fra 1992 til 1996 har jeg deltaget i tællinger af både moskus og rensdyr, hvor vi fløj med fastvinget fly. Under disse flyvninger flyver man i en højde af 150 meter, men til tider flyver man fra fjeldtop til fjeldtop uden at ændre højde, til trods for at der mellem disse fjeldtoppe kan være en dyb dal, hvor højdeforskellen kan blive op til 500 meter. Med fastvinget fly og derfor høj hastighed, og transektlinierne strakte sig fra Kangerlussuaq og helt op til Nordre Strømfjord. Flyvningerne kunne desuden vare i hele 8 timer ad gangen - ja - 8 timer i luften. Således var det helt sikkert, at man var træt og udkørt, når man havde fløjet i 8 timer.
Men flyvetællingen 2005 med helikopter var noget helt andet. Der flyves i en højde af ca. 15 meter i en hastighed af ca. 55 km/t, og man fulgte nøje landskabs-konturerne hele tiden, og piloten skal herunder roses for sin meget, meget flotte flyvning. Transekterne er 7,5 km, hvor vi fra 1992 til 1996 havde transekter, der kunne være 130 km i en strækning, og derfor er tællingen i år, set fra mit synspunkt, den bedste tællemetode, der er anvendt til dags dato. Vi kunne tælle det nøjagtige antal dyr, vi så, 300 meter fra fly og ud til siden, og kunne hele tiden notere os både rensdyr, ryper, harer, blå og hvide ræve.
Og en ting er helt sikkert, i dag lever rensdyr og moskus side om side, således er myten om, at de 2 dyrearter ikke tåler hinanden, helt hen i vejret, myten har måske været sand engang i tidernes morgen, men ikke i dag. I dag har de 2 arter simpelthen lært hinanden at kende.

m.v.h.
Hans Mølgaard
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Rink Heinrich &Johannes Egede - NUUK, 04 April 2005

Caribou survey of the Central region: Akia – Akia Nord

This survey was made between the 18 and 22 of March 2005. On this survey between Nuuk and Maniitsoq, Johannes Egede (Uti) and I, Rink Heinrich, participated as NAPP´s [Nuuk chapter of the commercial hunters organization, KNAPK] chosen observers.
In this region we noted that there were many cows and few bulls. We had heard that there were some muskoxen living in the Godhåbsfjord area, but we did not see any at this time.
The visibility was good for the entire survey and we enjoyed good teamwork. I would like to add, that this winter in the area south of Nuuk [not surveyed] there have been fewer caribou. A proper evaluation will be possible following next year's survey of this area.

Caribou survey of the North region: Kangerlussuaq and Nassuttooq

This survey was made between the 18 and 22 of March 2005. Hans Mølgaard, the hunting officer from Sisimiut, and myself , Rink Heinrich, participated as observers. During the survey we noted that there were more caribou than observed during the survey done five years ago. Further to this, we noted that a great amount of the region had been used by caribou as evidenced by the many caribou trails and paths. We have heard [from locals] that muskox and caribou can not abide each other, i.e. will not live in the same area. I can only say that this is not true, since during the survey we observed these two species grazing in close proximity and living harmoniously together.
Also, during this survey the teamwork was excellent, and I myself gained a wider knowledge.
I personly thank Christine [Cuyler] for the good teamwork during the surveys.
Finally I would like to mention that something must be done, e.g. laws or regulations, to conserve and protect the grazing areas of the caribou and muskoxen.

Yours truly

Rink Heinrich

Rink Heinrich &Johannes Egede - NUUK 04/04-2005 (in Danish)

Optælling af Rensdyr. Akia – Akia Nord

Optælling af rensdyr skete mellem den 14/03-2005.til og med 16/03-2005.
Til optællingen mellem Nuuk og Maniitsoq var jeg, Rink Heinrich, og Johannes Egede (Uti) med som NAPP´s valgte observatører.
I dette område bemærkede vi, at der var mange køer og færre tyre. Vi har før hørt, at der færdes moskusokser inde i Godthåbsfjorden, men vi observerede ikke nogen på dette tidspunkt.
Under hele optællingen var sigtbarheden god, og der var et godt samarbejde. Jeg vil lige tilføje, at der har været færre rensdyr i denne vinter syd for Nuuk, men jeg vil bedre kunne udtale mig omkring dette, når der er sket en optælling til næste år.

Optællingen mellem Kangerlussuaq og Nassuttooq

Optællingen skete mellem den 18/03-2005 til og med den 22/03-2005. Til optællingen var Hans Mølgaard, jagtbetjent fra Sisimiut, samt jeg, Rink Heinrich, med som observatører. Under optællingen har vi bemærket, at der var flere rensdyr end ved sidste optælling for 5 år siden. Og vi bemærkede også, hvor stor en del af landområdet der var betrådt af rensdyr og hvor mange stier og spor, der var dannet.
Vi har før hørt om at moskusokser og rensdyr kan ikke leve blandet i samme område. Dertil vil jeg kun sige, at dette ikke er sandt, da vi under optællinger har observeret, at disse dyr spiser og lever harmonisk side om side med hinanden.
Også under denne optælling var samarbejdet meget godt, og jeg selv fik en bredere viden.
Jeg vil personligt takke Christine for et godt samarbejde i disse optællinger.
Til sidst vil jeg lige nævne, at der bør gøres noget i lovgivningen for at bevare og beskytte disse dyrs græsningsområder.

Med venlig hilsen

Rink Heinrich

Rink Heinrich & Johannes Egede - NUUK 04/04-2005 (in Greenlandic)

Tuttunik kisitsineq. Akia – Akia Nord.

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Tuttunik kisitsineq. Kangerlussuaq + Nassuttooq

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